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Identifying Safe Load Moment Exposures for the Back

William S. Marras, Steven A. Lavender, Sue A. Ferguson,
Riley E. Splittstoesser, Gang Yang, Pete Schabo, Deborah L. Burr

Biodynamics Laboratory
The Ohio State University
1971 Neil Avenue
Columbus, OH 43210

Principal Investigator:

William S. Marras, Ph.D.
The Ohio State University
Institute for Ergonomics
Biodynamics Laboratory
1971 Neil Avenue
Columbus, OH 43210
Email: marras.l@osu.edu
Phone: 614.292.6670

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List of Abbreviations

LBD	Low Back Disorders
MMH	Manual Materials Handling
BMI	Body Mass Index
LMM	Lumbar Motion Monitor
CLMM	Clinical Lumbar Motion Monitor
Pn	Probability of Normal
NIOSH	National Institute for Occupational Safety and Health
METS	Moment Exposure Tracking System
DC	Distribution Center
EMG	Electromyography
CTD	Cumulative Trauma Disorders
AAE	Average Absolute Error
DSP	Digital Signal Processor
DAQ	Data Acquisition Boards
CART	Classification and Regression Trees
OR	Odds Ratio
RWL	1993 NIOSH Recommended Weight Limit
LI	1993 NIOSH Lifting Index

Abstract

Introduction. Low back disorders continue to be the most common and significant work-related musculoskeletal disorders in the US. Identifying what constitutes a “safe” physical workload from both the magnitude and temporal perspectives has been the biggest challenge facing injury prevention efforts. The goal of this project was to identify and quantify biomechanical risk factors, such as the load moment and duty cycle variables, that are predictive of low back disorders in distribution centers. The specific aims of this project were: (1) To develop new models based on an existing industrial exposure database. (2) To develop instrumentation so that the horizontal distance between the hands and the spine can be accurately measured for each lift performed over the course of an entire work shift. (3) To develop a database that contains the load moment exposures, hand position data, duty cycle parameters, and injury experience data. (4) To define via a prospective study the relationship between moment exposure parameters and the low back disorder incidence rates and disability measures. (5) To develop a simplified approach that can be used by practitioners to easily evaluate work tasks.

Methods. A sonic-based Moment Exposure Tracking System was developed to measure the physical exposure of the job continuously over an entire shift. A prospective study was designed to examine the low back health effect of workers in distributions centers. The physical exposure was measured on 195 workers on 50 jobs in 21 distribution centers. Low back injury rates were collected from the company’s records. The health effects measures included a Clinical Lumbar Motion Monitor (CLMM) functional performance, low back symptom survey, and psychosocial measures administered at baseline and 6-14 months follow-up.

Results. A new model based on the existing industrial database was built by dichotomizing the original variables. The sensitivity and specificity of the model have been improved. The accuracy of the Moment Exposure Tracking System (METS) has been tested and validated. The average error of the moment arm measurement was within 1.5 inches. For the prospective study, 451 workers who stayed on the same job at follow-up completed the low back functional performance test and the survey. The data captured by the METS was used to create a database that contains over 66,000 exertions quantifying load moment exposure, trunk and box kinematics, and duty cycle parameters from the 50 distribution center jobs. Multiple logistic regression models capable of predicting high risk jobs were developed based on both the incidence rate and the CLMM functional assessment. A combination of the mean of a job’s maximum resultant dynamic moments, mean of the maximum lateral trunk accelerations, and the mean duration of the exertions predicted the prospective change of low back functional performance with 70% sensitivity and 93.8% specificity. A combination of the average horizontal dynamic lift moment, the integrated lateral trunk acceleration, and the mean duration of the non-load exposure periods were predictive of incidence rate with 80% sensitivity and 87% specificity. Consistent with the final aim of the study, simplified models were developed to be used without specialized instrumentation. The average box weight and duration of exertion can be used to predict the high risk jobs defined by change of low back functional performance. The average of the peak horizontal static lift moments and the mean duration of the non-load exposure periods could be used to assess the job risk defined by the incidence rate.

Discussion. The models created represent the interactions between the force, motion, and frequency nature of the physical exposure. The correspondence between load moment, kinematic, and duty cycle variables entering the models based upon low back functional status and the incidence rate data is strong despite the longitudinal nature of the low back functional status and the cross-sectional nature of the incidence rate data.

Conclusions. Low back disorder risk can be characterized by combinations of the load moment exposure, trunk kinematics, and duty cycle descriptors. The specialized instrumentation developed in this study allows us to accurately quantify the physical exposure of manual materials handling jobs, and hence low back disorder risk in distribution centers. The combinations of dynamic moment, lateral trunk acceleration, and temporal variables are predictive of the change of low back functional status and injury rate. The simplified models presented in this report that do not require instrumentation can be used to identify high back injury risk distribution center jobs with reasonable sensitivity and specificity.

Significant Findings

The first specific aim was to develop new models based on an existing industrial exposure database. A new model was built based on the original variables in the LMM study database using classification and regression trees (CART), a powerful statistical software. By dichotomizing these variables, the sensitivity and specificity of the model have been improved. These models suggested that load moment, trunk kinematics, and temporal variables are strong indicators of low back disorder risks in manual materials handling environments.

The second specific aim was to develop instrumentation so that the horizontal distance between the hands and the spine can be accurately measured for each lift performed over the course of an entire work shift. A Moment Exposure Tracking System (METS) was developed to measure the moment arm, load weight, dynamic hand forces, trunk kinematics, box kinematics, and duration of exertions and rest periods simultaneously. The accuracy of the system has been validated with the moment arm measurement error less than 1.5 inches. This new instrumentation has significantly improved our ability to collect accurate physical exposure data on manual materials handling jobs, especially in the fast-paced distribution industry where load moment exposures can be highly variable.

The third specific aim was to develop a database that contains the load moment exposures, hand position data, duty cycle parameters, and injury experience data. A database that has all the above information collected from 195 distribution center workers on 50 jobs in 21 facilities was created. There were a total of 227 load moment exposure variables for each of the 66,854 exertions. This database allowed us to analyze the characteristics of the physical exposure of the MMH jobs observed. Dynamic, as opposed to static, moments have been found to better represent the true load moment exposure the workers experienced. The workers in the distribution industry have a large range of physical exposure levels in terms of dynamic trunk moments.

The fourth specific aim was to define via a prospective study the relationship between moment exposure parameters and the low back disorder incidence rates and disability measures. A prospective study was conducted in which low back functional performance was measured at baseline and follow-up, while the injury data were also collected cross-sectionally for the 3 years preceding the workplace assessments. Multiple logistic regression models for both the incidence rate (I200k) and low back functional test (Pn) were developed. The mean of a job's maximum resultant dynamic moment, the mean of the maximum lateral trunk acceleration, and the mean duration of exertions best predict the prospective change of Pn. The average horizontal dynamic lift moment, the integrated lateral trunk acceleration, and the duration of non-load exposure are predictive of the I200k data. These variables represent the interactive effect of load moment, trunk kinematics, and duty cycle on the risk of work-related low back injury.

The fifth specific aim was to develop a simplified approach that can be used by practitioners to evaluate distribution center tasks without the complex instrumentation developed in this project. Multiple logistic regression models were developed using only variables that are potentially available without the METS. The average box weight and

the mean duration of the exertions best predict the change of P_n , while the average of the maximum horizontal static lift moments and the average duration of non-load exposure could be used to assess the job risk defined by the incidence rate. Both models achieved reasonable sensitivity and specificity.

Translation of Findings

Findings from this study can be used to guide intervention efforts to prevent low back disorders in distribution centers. Reducing the load moment, minimizing the trunk lateral motion, and limiting the duration of exertions or increasing the rest period are likely to be most protective. The Moment Exposure Tracking System is a valuable tool that can be used in industry to evaluate the physical exposure level of manual materials handling jobs. When complicated instrumentation is not available, simplified approaches such as a spring scale, stop watch, and tape measure can be used to measure the box weight, the distance of the box to the lumbar spine, and the time of holding the load or the rest period. Cut-points in the model can be used as threshold values to assess if the job has a high risk of low back injury.

Outcomes/Relevance/Impact

The statistical models developed to predict high vs. low risk jobs can be used as risk assessment tools in the workplace to prevent low back injury. As such, they define low versus high risk exposure levels thereby providing targets for ergonomic intervention efforts including job design and work exposure controls. These results can be used to verify or modify the existing work recommendations for manual materials handling jobs in distribution environments.

Scientific Report

1. Introduction

1.1 Magnitude of Low Back Disorders (LBD) Problem

Back injuries are common in industry and extremely costly. Back pain continues to represent the most common and significant musculoskeletal problem in the United States leading to substantial amounts of morbidity, disability and economic loss (National Institute for Occupational Safety and Health, 2004; National Research Council and Institute of Medicine, 2001; Smith, Elliott, Hannaford, Chambers, & Smith, 2004; Morse, Dillon, Weber, Warren, Bruneau, & Fu, 2004; Kopec, Sayre, & Esdaile, 2004; Picavet & Hazes, 2003; Morken, Riise, Moen, Bergum, Hauge, Holien, Langedrag, Olson, Pedersen, Saue, Seljebo, & Thoppil, 2002; Hagen, Tambs, & Bjerkedal, 2002; Sweetman, 1999; Praemer, Furner, & Rice, 1999; van den Hoogen, Koes, van Eijk, Bouter, & Deville, 1997; Carey, Evans, Hadler, Lieberman, Kalsbeek, Jackman, Fryer, & McNutt, 1996; Andersson & Weinstein, 1994; Praemer, Furner, & Rice, 1992). Back disorders were responsible for the loss of half a billion lost workdays in 1988 with 22 million cases reported that year (Guo, Tanaka, Halperin, & Cameron, 1999). Among people under 45 years of age, LBD is the leading cause of activity limitation and effects up to 47% of workers with physically demanding jobs (Andersson, 1997). Pope (1993) has reported that the prevalence of LBD has increased by 2700% since 1980. The costs associated with LBD are vast. Early estimates of lost wages alone, amount to four billion dollars annually (Frymoyer, Pope, Clements, Wilder, MacPherson, & Ashikaga, 1983). Webster and Snook (1994) estimated that in 1986 the average direct costs of LBD was \$6,800 per case. Recent estimates of societal costs range from 25 to 95 billion dollars per year (Cats-Baril & Frymoyer, 1991).

1.2 Occupational Lifting and LBD Risk

The risk of LBD is associated with occupational tasks (Andersson, 1997). Thirty percent of occupational injuries in the United States are caused by overexertion, lifting, throwing, holding, carrying, pushing, and or pulling objects that weigh 50 pounds or less (National Safety Council, 1989). About one-fifth of all workplace injuries and illnesses are back injuries, accounting for up to 40% of compensation costs. Estimates of occupational LBD prevalence vary from one to 15% annually, depending upon occupation (Kelsey & White, 1980). Over a career, LBD can seriously affect 56% of workers (Rowe, 1971).

Low back disorders are associated with occupational lifting. The epidemiologic literature (National Research Council and Institute of Medicine, 2001; Andersson, 1997; Andersson, 1981; Burdorf & Sorock, 1997; Damkot, Pope, Lord, & Frymoyer, 1984; Marras, Lavender, Leurgans, Rajulu, Allread, Fathallah, & Ferguson, 1993; National Institute for Occupational Safety and Health, 1997; Frank, Kerr, Brooker, DeMaio, Maetzel, Shannon, Sullivan, Norman, & Wells, 1996; van Poppel, Koes, Smid, & Bouter, 1997) has noted that the type of work involved in an occupation is closely associated with

the risk of suffering a LBD. In particular, manual materials handling (MMH) activities, specifically lifting, dominate occupationally-related LBD risk. Retrospective studies (Spengler, Bigos, Martin, Zeh, Fisher, & Nachemson, 1986; Bigos, Spengler, Martin, Zeh, Fisher, Nachemson, & Wang, 1986) of industrial injuries have identified MMH as the most common cause of LBD. It is estimated that lifting and MMH account for 50% to 75% of all back injuries (Spengler, Bigos, Martin, Zeh, Fisher, & Nachemson, 1986; Bigos, Spengler, Martin, Zeh, Fisher, Nachemson, & Wang, 1986; Snook, 1989).

The nature of lifting is changing within industry. Previously much of the lifting exposure was associated with routine lifting in manufacturing facilities. However, the nature of work has changed significantly. More manufacturing jobs are performed outside of the U.S. borders yet the products produced are used within the U.S. This situation has led to a dramatic increase in the number of distribution centers (DCs) within the U.S. as products still need to be distributed within the country. In addition, internet ordering has also resulted in a large increase in DCs within the retail merchandising market (National Research Council and Institute of Medicine, 2001). Hence, increased exposure to frequent lifting will become even more of a factor as more workers are taking jobs in distribution which typically requires the manual movement of products.

Currently, many employers attempt to control risk through work standards. However, work standards are based upon the concept of “*a fair day’s work*” which is subjective in nature at best. At best, current work standards attempt to account for fatigue. None consider the effects of lift frequency upon cumulative trunk loading or the impact it may have on musculoskeletal risk. Hence, current work practice standards provide no protection from musculoskeletal disorders.

Since there are fewer manufacturing jobs in the U.S., there is less exposure of workers to *identical* repetitive lifting tasks. Instead, it is far more common to observe workers performing a variety of lifting tasks that involve more variation in load weights. In addition, rotation among jobs is fairly common in industries that expose workers to a vast variety of physical lifting conditions. *Hence, assessing cumulative exposures of load moments represents one of the few means available to quantify the features of modern lifting tasks.*

How much is too much with regards to manual lifting? The relationship between lifting frequency, lifting magnitude, and subsequent injury to the lower back has not been delineated to the point where one can provide guidance as to “how much exposure is too much exposure” for anything but the extreme lifting conditions. During the ergonomics standard debates over the work-relatedness of musculoskeletal disorders during the late 1990s many concerns were expressed by industry that the body of science could not specify the amount of exposure that was risky. Some of the OSHA testimony occurring during the ergonomics standard making process referred to “*the inability of science to determine the level of exposure, either in frequency or amount of weight, at which lifting becomes hazardous.*” In addition, several high profile scientists have seriously questioned the role of repetitive lifting in occupationally related LBD (Deyo, Psaty, Simon, Wagner, & Omenn, 1997; Hadler, 1986; Waddell, 1998). Hence, field studies that better describe LBD risk in the workplace are desperately needed.

1.3 Biomechanical Risk Factors of LBD

Back pain is believed to have a mechanical origin (Nachemson, 1966; Nachemson, 1975). Videman, Nurminen, & Troup (1990) also confirmed the notion that LBD risk was associated with physically heavy work, such as MMH, by examining the functional spinal units of 86 cadavers whose work and LBD history were known. They found increased degeneration in the spines of those specimens who had performed physically heavy work. Hence, these studies strongly suggest that occupationally-related LBDs are often associated with spine loading. Even though studies have also identified psychosocial (Bernard, Sauter, Fine, Petersen, & Hales, 1994; Bigos, Battie, Spengler, Fisher, Fordyce, Hansson, Nachemson, & Wortley, 1991; Bongers, de Winter, Kompier, & Hildebrandt, 1993; Burton, Tillotson, Main, & Hollis, 1995; Davis & Heaney, 2000) linkages to back pain, recent prospective studies have shown that both biomechanical factors and psychosocial factors can independently predict LBD (Krause, Ragland, Fisher, & Syme, 1998; Krause, Dasinger, Deegan, Rudolph, & Brand, 2001). In addition, recent studies have shown that psychosocial stress results in more biomechanical loading of the spine (Davis, Marras, Heaney, Waters, & Gupta, 2002; Marras, Davis, Heaney, Maronitis, & Allread, 2000). Hence, most researchers feel that biomechanical risk factors must be present before psychosocial factors are able to play a role (Marras, 2000; McGill, 2002). Since biomechanical loading is believed to be the primary injury pathway for occupationally-related LBDs, *this study has limited its focus to biomechanical risk factors.*

Low back disorders are cumulative trauma disorders (CTD) and closely associated with repetition. Repetition has been identified as a major risk factor for occupationally-related musculoskeletal disorders (Silverstein, Fine, & Armstrong, 1986). Even though LBDs are recorded as injuries or discrete events on OSHA 200 logs, most of the research community has recognized the cumulative or progressive nature of LBDs. Changes in the integrity of the intervertebral disc as well as changes in the ability of the vertebral endplates to nourish the disc are thought to relate to repetitive wear on the vertebral structures (Adams, Green, & Dolan, 1994; Maroudas, Stockwell, Nachemson, & Urban, 1975; Natarajan, Ke, & Andersson, 1994; Yingling & McGill, 1999). The cumulative effect of repetitive muscle activation has also been well documented in the physiological literature. Electromyography (EMG) studies indicate that repetitive lifting may fatigue the back muscle and the muscular load on the low back increases with higher frequency of lifting (Dolan & Adams, 1998; Nielsen, Andersen, & Jorgensen, 1998; Bonato, Ebenbichler, Roy, Lehr, Posch, Kollmitzer, & Della Croce, 2003). In addition, the cumulative influence of repetitive activities on biochemical reactions has also been documented in the literature (Barr & Barbe, 2002).

Given the cumulative trauma nature of occupationally-related LBD it is logical that repetitive occupational lifting should be considered a risk factor. Much of the literature supports this notion. Industrial surveillance studies (Marras, Lavender, Leurgans, Rajulu, Allread, Fathallah, & Ferguson, 1993; Marras, Lavender, Leurgans, Fathallah, Ferguson, Allread, & Rajulu, 1995) have reported that lift rates of above 120 lifts per hour increases

the probability of high risk group membership (for LBDs) for a job. This value agrees with the definition of CTD reported by Anderson (1988). Epidemiologic studies (Kelsey, Githens, White, Holford, Walter, O'Connor, Ostfeld, Weil, Southwick, & Calogero, 1984; Magora, 1975) have reported that repetitive lifting was indeed a risk factor for LBD. Epidemiology studies have also reported a dose-response relationship with increased lift frequencies associated with higher rates of low back pain (Kelsey, Githens, White, Holford, Walter, O'Connor, Ostfeld, Weil, Southwick, & Calogero, 1984; Chaffin & Park, 1973; Svensson & Andersson, 1983). Although the National Research Council's review of work-related low back and upper extremity disorders (National Research Council and Institute of Medicine, 2001) showed inconsistent evidence for repetitive movement to be a risk factor for LBD, only three studies were included for review. This suggests that an under-appreciated and under-explored risk factor for occupationally-related LBD is indeed frequency of lifting.

In a recent study Lavender, Oleske, Nicholson, Andersson and Hahn (1999) compared five low back injury risk assessment techniques in an automotive metal fabrication environment. These approaches included the Lumbar Motion Monitor logistic regression model, the National Institute for Occupational Safety and Health's Lifting Equation, the University of Michigan's Static Strength Prediction Program, and two variations of the UAW-GM Risk Factor Checklist. The modest inter-correlations between the approaches shows that even in metal fabrication, where variability in the magnitude of the loads handled and the lifting frequency is small relative to that encountered in distribution centers, there was limited agreement between measures. In other words, there is limited agreement in the answer to the question "how much is too much?" It is also reasonable to assume that with the greater variation in the items handled and temporal spacing between lifts found in distribution centers, the agreement between these techniques would be degraded. Moreover, the application of these ergonomic assessment techniques would be extremely challenging (Waters, Baron, Piacitelli, Anderson, Skov, Haring-Sweeney, Wall, & Fine, 1999) and may be of questionable validity. In large part, this is because current ergonomic assessment techniques have not been developed to examine the variation in load magnitudes or the temporal parameters that would describe the duty cycle. Thus, there is an urgent need to develop models that can accommodate the range of workload variation encountered in distribution centers so that safe exposure levels to repetitive lifting can be determined. We believe based on our previous work and the literature that such models will ultimately be based upon the selected parameters characterizing the load moment exposure and selected parameters characterizing the duty cycle.

1.3.1 Load Moment Exposure Measures

The underlying assumption of biomechanical reasoning is that risk of injury occurs when the load imposed upon a tissue exceeds the tolerance of a tissue (McGill, 1997). Numerous studies, using validated 3-dimensional models of spine loading have demonstrated how exposure to increases in load moment increases the compression, shear, and torsion forces on the spine (Bean, Chaffin, & Schultz, 1988; Cholewicki & McGill, 1996; Cholewicki, McGill, & Norman, 1991; Davis, Marras, & Waters, 1998; de Looze, Kingma, Thunnissen, van Wijk, & Toussaint, 1994; Granata & Marras, 1995;

Granata & Marras, 1999; Hughes & Chaffin, 1997; Marras & Davis, 1998; Marras & Granata, 1995; Marras & Granata, 1997; Marras & Granata, 1997; McGill & Hoodless, 1990; McGill & Norman, 1986; Nussbaum & Chaffin, 1998; Thelen, Schultz, & Ashton-Miller, 1995). In addition, numerous studies have demonstrated that the tolerance limits of the spine tissues can be easily exceeded with exposure to even moderate load moment (Natarajan, Ke, & Andersson, 1994; Yingling & McGill, 1999; Barr & Barbe, 2002; Abbrecht, 2001; Adams, 1988; Adams, 1995; Adams, Freeman, Morrison, Nelson, & Dolan, 2000; Adams, Hutton, & Stott, 1980; Barr & Barbe, 2004; Barr, Safadi, Gorzelany, Amin, Popoff, & Barbe, 2003; Brinckmann, Johannleweling, Hilweg, & Biggemann, 1987; Brinckmann, Biggemann, & Hilweg, 1989; Callaghan & McGill, 2001; Callaghan & McGill, 2001; Hutton, Elmer, Bryce, Kozlowska, Boden, & Kozlowski, 2001; Hutton, Murakami, Li, Elmer, Yoon, Minamide, Akamaru, & Tomita, 2004; Iatridis & ap Gwynn, 2004; Iatridis, Kumar, Foster, Weidenbaum, & Mow, 1999; Jager, Luttmann, & Laurig, 1991; Lotz & Chin, 2000; Solomonow, 2004; Yingling & McGill, 1999). There is also limited evidence to suggest that these mechanical assessments of load relate well to observed injury patterns in the workplace (Granata & Marras, 1999). Thus, there appears to be ample evidence to suggest that worker exposure to load moment represents a plausible pathway to LBDs.

If one examines the underlying structure of NIOSH recommendations for lifting, we can see that the most powerful factor in these assessments is associated with load moment. NIOSH developed two documents intended to provide guidance to industry regarding the hazards associated with a MMH situation. These documents are based upon multiple criteria in that they consider biomechanical limits as well as physiological and psychophysical limits. Both the 1981 Guide as well as the 1993 Revised Equation “discount” the acceptable load limit based upon a series of factors including the horizontal distance and the frequency of lift. These tools were assessed for their ability to predict LBD risk based upon data from 353 industrial jobs representing over 21 million worker hours of exposure (Marras, Fine, Ferguson, & Waters, 1999). The results indicated that both NIOSH measures were predictive and resulted in odds ratios between 3.1 and 4.6. Thus, this study provided epidemiologic evidence demonstrating the significant importance of load moment.

For comparison purposes, the predictive power of the load moment supported by the trunk was evaluated. This factor produced an odds ratio for high risk vs. low risk of LBD of 4.08 (C.I. 2.62-6.34) using average moment arm distance (horizontal distance) and 5.17 (C.I. 3.19-8.38) when maximum horizontal distance was used to compute moment (Marras, Fine, Ferguson, & Waters, 1999). These values were significantly greater than any other single measure. In addition, this odds ratio was greater than the odds ratio produced by either the 1993 or 1981 NIOSH Guide models. For the case of the jobs observed in this study knowledge of this simple factor alone would enable one to identify those jobs that were high risk vs. low risk of LBD as well as the more computationally intensive measures. However, we should caution that this might not hold true for jobs with work parameters that are outside the range of those observed in this study. For example, the database does not contain observations of jobs where lifting was performed from an extremely low or high vertical location. Thus, we cannot evaluate how well the NIOSH approach would work in identifying risk in those positions.

In summary, the literature suggests that load moment knowledge is essential to understanding the load-tolerance relationship of the spine and the subsequent risk of LBD.

1.3.2 Duty Cycle Measures

Several studies have suggested that the temporal aspects of lifting are extremely important in the recruitment behavior of the trunk musculature, the loading of the spine, as well as the risk of LBD (Marras, Lavender, Leurgans, Fathallah, Ferguson, Allread, & Rajulu, 1995; Marras, Fine, Ferguson, & Waters, 1999; Fathallah, Marras, & Parnianpour, 1998; Marras, Allread, Burr, & Fathallah, 2000). In our earlier industrial surveillance study (Marras, Lavender, Leurgans, Rajulu, Allread, Fathallah, & Ferguson, 1993), we found that the number of lifts individuals performed per hour significantly contributed to the risk of low back disorder and was therefore included in the multivariate risk model. The “lift rate” data were based upon average number of lifts that would be performed over the course of an 8-hour day. Dolan and Adams (1998) had their subjects lift 10 kg 100 times. They found that over the course of the 100 trials the bending moment on the spine increased by 36% as the participants fatigued. Similarly, others have shown changes in trunk kinematics when lifts are repeatedly performed that simulate conditions found in distribution center (Marras & Granata, 1997).

Biomechanical studies suggest that cumulative load exposure may provide a promising measure of LBD risk. A limited number of studies have explored the use of cumulative exposure measures to describe spine loading. Kumar (1990) used a 2-dimensional static model to describe cumulative load in 161 workers and found that those exposed to greater cumulative loading were more apt to report injuries. One recent laboratory study has explored the relationship between discrete “features” of continuous cumulative loading and actual continuous integrated 3-dimensional spine loading during lifting (Callaghan, Salewytch, & Andrews, 2001). Discrete features of continuous cumulative load profiles involve measures such as peak exposure or average exposure as a summary of integrated exposure. Some have suggested that these measures may be used as a summary of cumulative exposure. However, the authors demonstrated that descriptions of these cumulative discrete features can result in up to 69% error compared to a continuous measure of load exposure. The same study indicated that continuous biomechanical load profile can be sampled as low as 5 Hz and still accurately preserve the lifting profile.

Recently, our laboratory has completed a NIOSH-sponsored study that examined how 3-dimensional dynamic biomechanical loading of the spine changes over an 8 hour lifting exposure and as a function of lift frequency. This study indicated that cumulative exposure time was more indicative of spine loading increases than was exposure to lift frequency (Marras, Parakkat, Chany, Yang, Burr, & Lavender, 2006). Hence, there is a complex relationship between temporal aspects of load and cumulative risk exposure. However, this study suggests that there is a biomechanical underpinning to cumulative load exposure that should be considered in the characterization of occupational risk exposure.

These findings on repetition suggest a link between the temporal aspects of manual materials handling tasks and the resulting spine loads. Therefore, the work and rest period parameters that describe the duty cycle would likely have a profound effect on the biomechanical aspect of the biomechanical loadings experienced by workers in fast-paced material handling jobs. *Unfortunately no biomechanical or epidemiological assessments have adequately investigated lift frequency in such a way that safe versus unsafe duty cycles could be derived.*

In conclusion, this brief review has shown that occupationally-related LBD are often associated with repetitive material handling jobs. However, our knowledge of the exposure-injury relationship is not well defined. Because this relationship is poorly defined there is a significant void in our knowledge when it comes to providing simple straightforward advice to industry in identifying what constitutes a safe amount of lifting both in terms of load magnitude and in terms of duty cycle. This is especially true in environments where the magnitudes of the load lifted and the temporal spacing of the lifts are highly variable. The work done to date supports the hypothesis that the answer to the question “How much exposure is too much exposure” is likely to be answered in terms of parameters describing the load moment magnitude and the duty cycle. This prospective study seeks to define this relationship in such a way that it can account for the normal range of variation in load moment exposures experienced by workers.

1.4 Existing Industrial Exposure Database

Research efforts that have worked towards understanding the loading and risk associated with free-dynamic lifting have been underway in the Biodynamics Laboratory at The Ohio State University for the past 20 years. One component of this research effort has focused on field surveillance of MMH activities. There were two objectives of the field surveillance studies. First, these efforts intended to describe the trunk motions used by workers exposed to occupational MMH activities. Second, the field surveillance studies assessed the associations between the trunk motion and workplace characteristics, and the risk of suffering an occupationally-related LBD. Our surveillance studies (Marras, Lavender, Leurgans, Rajulu, Allread, Fathallah, & Ferguson, 1993; Marras, Lavender, Leurgans, Fathallah, Ferguson, Allread, & Rajulu, 1995) have been successful in both of these efforts. A tri-axial lumbar motion monitor (LMM) has been developed in the Biodynamics Laboratory at the Ohio State University in order to facilitate on-the-job lumbar motion assessment and documentation. This device is a portable exo-skeleton that is worn on the back of a worker and tracks the motion profiles of the spine during industrial work. It measures the three-dimensional position, velocity and acceleration of the lumbar spine and can be effectively used in the workplace to perform real-time data collection.

The LMM was used to assess the contribution of three-dimensional dynamic trunk motions to the risk of LBD during occupational lifting in industry (Marras, Lavender, Leurgans, Rajulu, Allread, Fathallah, & Ferguson, 1993; Marras, Lavender, Leurgans, Fathallah, Ferguson, Allread, & Rajulu, 1995). Over 400 industrial manual material handling jobs were studied in 48 various industries. The injury records (OSHA 200) and turnover rates from each job were examined in order to quantify occupationally-related

LBD risk. Workers in these jobs wore the LMM so that the three-dimensional angular position, velocity, and acceleration characteristics of the lumbar spine could be measured as routine tasks were performed. Workplace and individual characteristics such as load moment arm, load weight, lift origin and destination, lifting frequency, and worker satisfaction were also documented for each of the repetitive lifting tasks. This effort made it possible to describe the range and distribution of trunk motions and workplace factors observed in the MMH workplace (Marras, Lavender, Leurgans, Rajulu, Allread, Fathallah, & Ferguson, 1993) as well as describe the features of high, medium and low risk MMH jobs (Marras, Lavender, Leurgans, Fathallah, Ferguson, Allread, & Rajulu, 1995). A multiple logistic regression risk model indicated that a combination of five trunk motion and workplace factors were highly predictive of occupationally-related LBD risk (odds ratio 10.7, C.I. 4.9-23.6). These factors included: 1) lifting frequency, 2) load moment, 3) trunk lateral velocity, 4) trunk twisting velocity, and 5) the trunk sagittal flexion angle. Increases in the magnitude of these factors significantly increased the risk of LBD. This study demonstrated the added benefit of considering dynamic trunk motion in addition to the classic workplace variables in risk prediction.

1.5 Current Load Moment Exposure Measurements

Historically, load moment has been documented by measuring the horizontal distance of the load from the spine using a tape measure (see Figure 1-1) and multiplying this distance by the weight of the load lifted, where the load weight is measured with a scale. This type of approach, while feasible in manufacturing environments where the lifting tasks tend to be cyclic and included limited variation, would be very difficult to implement in distribution center environments where the lifting situation often changes from one lift to the next as does the weight of the object being handled. In order to develop a system that is capable of accurately assessing load moment it was necessary to assess the fidelity of the current means of measuring load moment for benchmarking purposes.



Figure 1-1. Traditional method for moment arm measurement.

An experiment was performed involving a task in which the moment arm distances measured by four experienced (moment arm) data collectors were compared with

moment arm measures derived from a magnetic tracking device that was capable of monitoring distances (to within one inch of accuracy) in a laboratory setting. The Motion MonitorTM was used to measure the distance between a case load defined as the point at which a worker lifted an object and the horizontal distance from the spine. The Motion Monitor consists of a transmitter and several 6-degree-of-freedom receivers (birds). The transmitter emits magnetic pulses at a user defined sampling rate. The birds consist of coils that are identifiable within this magnetic field.

The subjects were required to measure the moment arm distances of a person lifting boxes from 7 different origins to 8 different destinations. Each trial was performed once with a person lifting asymmetrically from left to right and once lifting from right to left. A total of 16 lifts were observed for each subject. The *dependent measure* consisted of the average absolute error (AAE) indicating the difference between the magnetically derived moment arm distance and the moment arm measured by the data collectors.

The results indicated that the average AAE of all data collectors was 4.3 inches with a standard deviation of 2.3 inches. Individual subject AAE ranged from 2.9 inches to 6.0 inches. Hence, this analysis indicated that an instrumented moment arm measurement system would be substantially superior to experienced human data collectors if it was capable of measuring moment arm distances with AAEs of 2.5 inches or less.

Technologies considered for instrumented dynamic moment tracking system: In order to develop an instrumented moment monitor system several technologies were considered. First, microwave transmission was considered and a simple prototype system was tested. This system attempted to reflect microwave signals off of a target and use timing data to measure the distance of the object from the body. While the system worked reasonably well for targets that were perpendicular to the microwave transmission source, any deviation from this position tended to reflect the signal in a direction that was not picked up by the receiver. Under distribution center environment conditions many objects are handled that would violate this requirement. Thus, the microwave technology was eliminated from consideration.

Second, magnetic tracking technology has been considered and tested in a Distribution Center environment (Figure 1-2). In order to make this system portable within a distribution center, it was necessary to mount the transmitter on the back of the worker. This would provide a measurement reach envelope of 50 inches. However, this system had several drawbacks, the first of which being the weight of the equipment. This would come from the transmitter device as well as the significant portable power source (battery) that would be required. The combined weight of these two system components would be expected to alter the lifting movement. In addition, since this approach used a magnetic tracking device, metallic structures, such as the racks from which the workers were lifting would likely interfere with the signals. Thus, this technology was also eliminated from consideration.

Third, a goniometric system of tracking the hands relative to the back was considered. A goniometric “suit of sensors” was considered. However, this system would require multi degree of freedom measurements at the major articulations of the body. In particular the

shoulders presented a significant challenge for such a measurement option. In addition, each system would need to be calibrated relative to the individual worker, which would require a substantial amount of set up time. Hence, this technology was also dismissed.

Fourth, the Gypsy™ angular acceleration/gyroscope system was considered and tested. This commercial system is used for film animation purposes and is intended to permit free motion of the various limbs of the body. Upon testing of this system, it was discovered that this system needed to be strapped to many locations on the body did not permit natural movement of the body (Figure 1-3). It was also determined that this system would not withstand the rigors of a distribution center workplace.

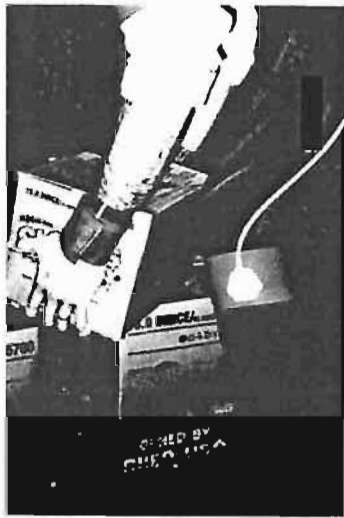


Figure 1-2. The sensor positions on the wrist and the legs were used to track hand positions in 3D space using the magnetic tracking technology.



Figure 1-3. Gypsy angular acceleration/gyroscope system considered as a moment measurement technology.

Finally, ultrasound (sonic) technology was considered. This technology can measure distance by tracking directional ultra high frequency sound. The technology has been widely used as a focusing mechanism on cameras where ultra high frequency sound is bounced off a subject and received by the camera's ultrasound sensor. The time it takes this signal to be emitted from the camera and return is a measure of the distance from the subject. This technology has the advantage that the transmitters and receivers are relatively small, light and inexpensive. Thus, multiple transmitters and receivers can be wired together in a system that could triangulate a target, thereby providing information about target distance, height, and orientation. For these reasons ultrasound was chosen as the technology with which to build a moment monitor system.

1.6 Specific Aims

The long-term aim of this research is to reduce the incidence of low back injury in manual material handling (MMH) jobs. Epidemiologic studies have shown the link between repetitive lifting and occupationally related low back injury. However, the biggest challenge facing injury prevention efforts is determining what constitutes a “safe” physical workload with respect to the prevention of work related low back disorders, or conversely, “how much is too much exposure” to manual lifting. While there are data to support lower spine stresses in material handling jobs result in less injuries, the models that can predict injury based on workplace exposure measurements are limited in terms of their application either due to their complexity, due to their reliance upon expensive measurement devices, or due to their lack of validation. Thus, a simpler method is required for assessing workplace exposure to low back disorder risk.

The underlying *hypothesis* of this study is that parameters describing the load moment, when combined with duty-cycle (temporal loading) descriptors of the exposure levels, are predictive of low back disorder measures. Thus, there is a need to identify and quantify the key parameters, both in terms of the load moment and in terms of the duty cycle, that are predictive of injury where repetitive lifting occurs. Ultimately the goal of the study is to develop a simple model that can be used to determine whether or not workplaces are safe with respect to their back injury risk level.

In achieving the overall goals of this project the study addressed the following *specific aims*:

- 1) To develop new models based on an existing industrial exposure database.
- 2) To develop instrumentation so that the horizontal distance between the hands and the spine can be accurately measured for each lift performed over the course of an entire work shift.
- 3) To develop a database that contains the load moment exposures, hand position data, duty cycle parameters, and injury experience data.
- 4) To define via a prospective study the relationship between moment exposure parameters and the low back disorder incidence rates and disability measures.
- 5) To develop a simplified approach that can be used by practitioners to easily evaluate work tasks.

2. Methods

2.1 Preliminary Modeling Based on an Existing Industrial Exposure Database

We already have a database of 515 manufacturing jobs that allows us to develop and test some preliminary models that relate load moment and lifting frequency to historical incidence rates. Classification and Regression Tree (CART) software has been developed

since the initial analysis of this data (Marras, Lavender, Leurgans, Rajulu, Allread, Fathallah, & Ferguson, 1993). By examining the existing database with the new CART software, we might be able to improve on the model developed by Marras et al (1993). CART is a powerful technology originally developed by Breiman et al (1984), and now commercially available from Salford Systems (Steinberg & Colla, 1997). The Breiman et al reference contains a full and detailed explanation of the methodology, theoretical justification, and examples from several fields, including medical. The other reference, from Salford Systems, is a user's manual for their user-friendly version of the software; it gives full details about the practical implementation of CART. In this report, only certain applications of CART (i.e., for classification of a dichotomous outcome variable) were used and will be explained as needed.

A few basic features of CART are described here. The CART method results in a "tree" by which a worker will be classified as "got worse" or "not worse". The classification is accomplished by figuratively dropping the job down the nodes of a tree by answering yes-no questions as to whether the job has a variable value above or below a CART generated cut point. The method is highly computer-intensive. For example, to determine the best initial split of the data, CART considers all available predictor variables split at all possible values, computes a numerical "goodness-of-split" criterion for each split, and chooses the variable and split point with the best criterion value. The method is completely nonparametric, and local (i.e., based on the data being examined). Once the dataset is split, the data on the left and the right are treated separately in making further splitting decisions. CART was designed for the problem of automatically doing variable selection from a large number of predictor variables. The method solves the problem of "over-fitting" by first growing the largest possible tree, then "pruning" it back, and selecting the final tree based on a cross-validation procedure comparing all the possible sub-trees of the initial big tree. The final output produces honest estimates of misclassification error rates (by default, using 10-fold cross-validation).

After using CART to determine cut points for each predictor in the database univariate logistic regressions were performed for each variable. All the logistic regressions were weighted based on the number of person-hours from which the injury rates were derived as in the original analysis. Next, multiple logistic regression was used to build the original model with dichotomized variables instead of continuous. In this method, both the predictors and the outcome variables were dichotomized. Goodness-of-fit was assessed at each stage of model-building via residual analysis and the Hosmer-Lemeshow goodness-of-fit test. Criteria for model selection include statistical significance of the predictors (deviance and Wald tests) and biomechanical plausibility. The area under the ROC curve is a statistical criterion for model strength, analogous to R^2 in linear regression, and was used for model selection as well. Computation was done using SAS PROC LOGISTIC.

2.2 Ultrasound Moment Arm Tracking System Development

2.2.1 Prototype Development

In order to test the feasibility of an ultrasound moment arm tracking system a prototype hardware system was developed. The system hardware resided on a backpack frame that contained the ultrasonic receivers, data acquisition system, accelerometers, and a wearable computer.

Figure 2-1 shows some of the critical hardware components of this system. Figure 2-1(a) shows a cluster of ultrasound transmitters that are used to generate the ultrasound signal. These transmitters are placed at the hands (Figure 2-1(b)) and serve as targets for the box location. Figure 2-1(b) also shows a series of ultrasonic receivers worn on the chest and waist belt of the subject. Figure 2-1(c) shows a series of three receivers placed at the ends of flexible springs attached to the backpack frame. Each sonic receiver was connected to a preamplifier and a hardware filter. A three dimensional accelerometer, mounted to the backpack frame, allows back bending and acceleration data to be monitored. The accelerometer and receivers were monitored by two National Instruments data acquisition (DAQ) cards that sequentially sampled each signal at a rate of 20 Hz. Data were collected on the computer using a custom Visual BasicTM application to run the DAQ boards. The DAQ cards were connected to a wearable computer running a WindowsTM operating system (Figure 2-1(d)). Data were transmitted via a wireless network as well as stored on a flash card for later download. The initial version of the entire backpack system weighed 27 lbs.

The *system logic* was designed so that ultrasonic “pulses” were generated from the hand transmitters at regular intervals (20 kHz). The receivers placed on the backpack frame and backpack straps sampled the reception of the transmitted signal in a set sequence. The system was capable of differentiating the timing between receptions at the various receivers, thereby determining the linear distance of the transmitter from the receiver. The system’s software used the linear distance information from the various receivers to “triangulate” the target. The accelerometer was used to account for torso bending which could influence moment arm distance from the spine. It was also used to compensate for knee bending which would influence the starting height of the lift.

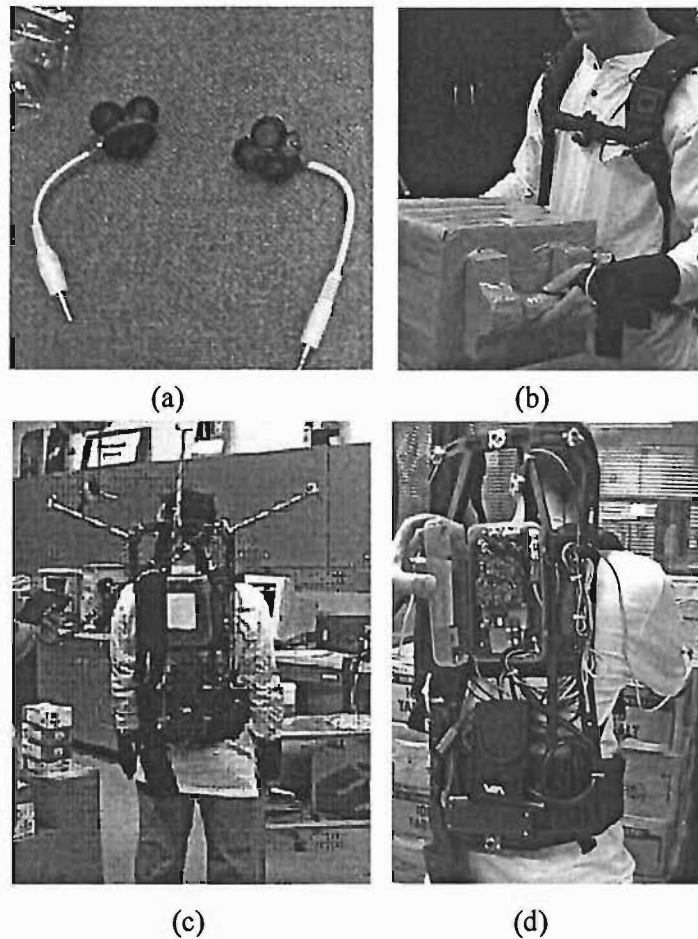


Figure 2-1. Sonic (ultrasound) receiver cluster (a), sonic transmitters mounted on the subject's hands and receivers visible on the backpack belts (b), backpack hardware system with receivers protruding from the backpack frame (c), and a close up view system electronics including the DAQ board, accelerometer (black box at base of backpack), and wearable computer (black pouch) (d). The prototype system weighed 27 pounds.

Prototype System Testing – The prototype system moment arm measurements were compared with the traditional means of monitoring moment arms. A subject moved boxes from a distribution center “slot” to a pallet jack in a laboratory setting. An experienced data collector recorded moment arms using a tape measure. These traditional measures were compared to the moment monitor predictions over all levels of lifts from the top to the bottom of the pallet. Initial system estimates of moment arm compared to the traditional (human) measures yielded an average absolute error (AAE) of 7.1 inches. AAE over the 60 trials varied as a function from pallet layer from a low of 4.5 inches to a high of 8.5 inches. This analysis indicated that the system produced “reasonable” estimates of moment. However, when interpreting these results one must keep in mind that the human error (to which the system is compared) exceeds 4 inches.

Prototype Field Testing – A field test of the ultrasonic moment arm tracking system was performed in a local distribution center (see Figure 2-2). The prototype was modified for use in the distribution center in that the receiver extensions shown in Figure 2-1(c) were removed. A subject wore the prototype for a three hour period. The field test yielded two important types of information. First, ultrasonic tracking of the target (hand location) appeared to be a feasible technology to monitor hand positions in an actual distribution environment. The system generally worked well with only minor problems of associated with visibility of the transmitter. The research team believed that these visibility issues could be remedied with some rearrangement of the receivers on the backpack.



Figure 2-2. Prototype testing at a local food distribution center.

Second, the workers were asked about whether the backpack system interfered with their lifting style. All workers commented that they felt the weight of the backpack was a hindrance to their work and indicated that the backpack was also hot and contributed to fatigue. These problems could potentially influence lifting style and, therefore, moment arm measurements. Thus, the field test indicated that it was necessary to dramatically reduce the size and weight of the backpack system.

2.2.2 Development of a Load (Force) Monitoring System

An integral part of load moment determination involves the assessment of the load characteristics. As mentioned earlier, load characteristics have historically been determined by simply weighing the object being lifted using a simple spring scale and storing this information along with the moment arm calculation for eventual calculation of the load moment. However, this simplistic means of determining load characteristics has several limitations when it comes to assessing load moment exposures in distribution center work. First, only static load moment can be calculated. Recent biomechanical studies have indicated that static assessments grossly misrepresent the loading of the tissue (Granata & Marras, 1999; Marras & Granata, 1997; Granata & Marras, 1995; Marras, 1992). Hence, the static load moment may significantly under represent the true load moment exposures that could be assessed through instrumentation capable of measuring the dynamic forces applied. Second, unlike manufacturing operations, often

each item handled in distribution environments is unique and would have to be manually weighed. In these fast-paced environments, weighing each item would likely interfere with the worker's job performance or some weights not being obtained. In either case, the assessment of the cumulative load moment exposure and the measurement of parameters describing the temporal distribution of the exposure would be of questionable validity. For these reasons, the research team decided it would be beneficial to develop an automated system to measure and record dynamic and static load characteristics.

The recording of load characteristics during lifting requires the mass and acceleration characteristics of the load lifted be measured. In terms of instrumentation, this required that a series of strain gauges and accelerometers to be placed in between the hands and the box lifted. LiftMates™ hand holds were used to house the instrumentation and serve as an interface between the load lifted and the hands. This component of our data collection system is shown in Figure 2-3. The handhold system consists of a compressible rubber handle that comfortably fits the hand. This handle is connected to a series of small (1/8") pins (pin pad) that interface with the box and, therefore, provide a handhold for the box.

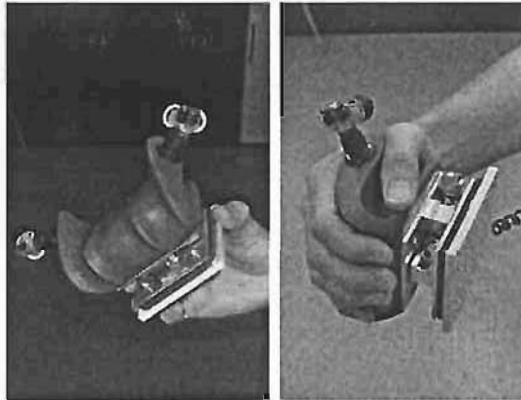


Figure 2-3. LiftMates™ lifting handhold system used to house the strain gauge and accelerometer systems.

At the interface of the handles (hand attachment point) and the "pin pad" (load attachment point) are four digital load cells (strain gauges) and four analog accelerometers that record data at a rate of 1 KHz. The strain gauges and accelerometers are arranged in such a way that load information is recorded in the up-down dimension of the box (in order to account for lifting mass) as well as the front-back dimensions of the box (to account for box tilt). Each handle contains one DAQ board with 8 analog inputs and 4 digital inputs. The DAQ boards communicate over a 1Mbps CAN-bus with a central SDP card (located in the back pack) coordinating all operations. This arrangement makes it possible to record the mass and acceleration experienced by each hand during a lift. In this manner, the static load weight and the dynamic load experienced by the hands can both be obtained. Figure 2-3 also shows that the handles are also used as an attachment points for the sonic transmitters on both the top and bottom of each handle.

Calibration Testing – The handhold system voltage output was compared in each direction (vertical and sideways) over a series of known weights that varied from zero to

100 pounds. An example of this calibration is shown in Figure 2-4. Combinations of load directions were also tested. Overall, good relationships were observed between the output and weight with the predicted weight being within one pound of the actual weight across the tested range.

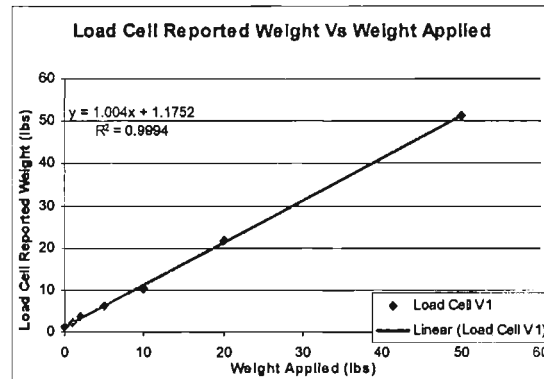


Figure 2-4. Example of force calibration associated with one dimension of handle transducer.

2.2.3 Second Generation Moment Tracking System Hardware Development

The goal of the second generation system instrumentation was to integrate the load monitoring capabilities just described with a smaller, less cumbersome moment arm tracking system. Collectively these load and moment arm tracking technologies comprise the Moment Exposure Tracking System (METS). In order to accomplish this several changes were made compared to the original prototype. The wearable computer and data acquisition system was replaced with miniature Digital Signal Processor (DSP) Data Acquisition Boards (DAQ) with an integrated CAN-bus. There are 3 custom made Digital Signal Processor (DSP) Data Acquisition Boards (DAQ) with integrated CAN-bus in the system. Each board contains 8 analog inputs and 4 digital inputs. One DSP board is in each handle and one resides in the main processor located on the backpack. All boards communicate over a 1Mbps CAN-bus with the main processor DSP coordinating all operations. The DSP boards sample each channel at 1 kHz. Analog data is preamplified just prior to the DSP card. As discussed in the previous section, the handles each collect 2 load cell digital channels and 3 accelerometer analog channels at 1 kHz each and drive two sonic transmitters each. Each of the 4 transmitters fire at a 12.5 Hz rate. Transmitter firing is coordinated by the main processor located on the backpack so that the transmitters fire in sequence, not simultaneously. Thus, a complete picture of the location of both hands is available at 12.5 Hz and an update to this location is available at 50 Hz ($50 \text{ Hz}/4 = 12.5 \text{ Hz}$ rate for each transmitter).

The backpack accelerometer was also replaced with a small accelerometer "chip." This change not only reduced the weight of the backpack but, is also much less expensive than

the original accelerometer configuration. The accelerometer records data in the sagittal and lateral dimensions and is capable of monitoring forward and lateral orientation changes of the backpack.

DSP data are output to a data bridge card located in the black box via RS232 signal at 114 Kbaud. This signal is simultaneously written to a flash card and broadcast via radio where it can be recorded using a wireless internet connection-enabled computer. A picture of the second generation METS is shown in Figure 2-5. The total weight of the system is only 7.5 pounds (including the handles) compared to a weight of 27 pounds for the original prototype system.



Figure 2-5. Second generation Moment Exposure Tracking System (METS) weighing less than 7.5 pounds and allows for free movement during lifting operations.

2.2.4 Available Data Types and Collection Frequency

Since the METS system uses a number of different instruments, data processing techniques and collection frequencies vary across data types. Table 2-1 shows types of data available from the METS system and the effective maximum collection frequency for each data type.

Table 2-1. Data types, sources and collection frequency from the METS system

Data Type	Data Source	Collection frequency (Hz)
Box Position	Sonic transmitter/receivers	50
Box Velocity	Integration of Box Acceleration	1000
Box Acceleration	Handle Accelerometers	1000
Hand Force	Handle Load Cells	1000

Trunk Angle	Backpack Accelerometers	1000
Trunk Angular Velocity	Derivative of Back Angle	1000
Trunk Angular Acceleration	Derivative of Back Angular Velocity	1000

2.2.5 System Software Development

The software reads in accelerometer data from each handle and the backpack, load cell data from each handle, and ranging (distance) data between each receiver and each transmitter. The software calculates the hand force and load mass using the load cell and accelerometer data. The accelerometer data are also used to determine the orientation (angles) of each handle in space as well as orient the backpack in space.

In order to help triangulate the location of the target, the software performs a least squares fit on the ranging data to determine the location of each handle relative to the backpack using the known locations of each receiver on the backpack. Where the ranging data disagrees on the location of each transmitter or if data are absent for a particular transmitter, the software uses the orientation data from the handle load cells and performs multiple iterations to determine the optimal transmitter location. This optimization initially places the transmitter at a set point in front of the body and calculates the residuals between the ranging data and the initial placement. The transmitter is then moved a small amount in one direction and residuals recalculated. If these residuals are smaller than the original, the transmitter is iterated farther in that direction. If not, another direction is attempted. This iteration continues until the residuals do not decrease if the transmitter is moved in any direction. Constraints are used to keep the software from finding a duplicate solution that would place the transmitter behind or inside the body. After the optimization, the location of each transmitter is then used to locate the box (midway between the hands).

Subject anthropometry (height, weight, depth and breadth at the xyphoid process and the iliac crests) is also used to identify the location of the subject's L5/S1 joint. The software then calculates the horizontal distance between the box and L5/S1 as well as the height of the box from the floor. These data are then combined with the force/mass data to determine moment, box height, etc.

The software has been designed so that features of a lift event can be compiled easily for statistical evaluation and comparison purposes. One of the benefits of an instrumented METS such as this is that voluminous amounts of data can be easily reduced to an immediately usable data set through proper software manipulation. The software serves several functions. First, the software can be used to assess system status and can be used to visually assess the "visibility" of each receiver, the trunk angle, and the load location of the box lifted relative to L5/S1 at any point in time (lower right portion of Figure 2-6).

Second, the software can be used to "initialize" the system by allowing the user to calibrate the system relative to any unique conditions. The "strength" of any given receiver can be increased or decreased to adjust visibility windows.

Third, the software records continuous information used to calculate the instantaneous load moment at each point in time. The software is designed to assess specified features of the lift event and write the information to a file (lower left hand portion of Figure 2-6 and Figure 2-7, different lines represent different lifts). Among the lift event features recorded are:

- Time of day
- Time since last lift
- Duration of lift
- Initial moment arm
- Continuous moment arm
- Final moment arm
- Load acceleration
- Box weight
- Dynamic force
- Peak static moment
- Cumulative static moment
- Peak dynamic moment
- Cumulative dynamic moment
- Average dynamic moment per second
- Height of lift

Finally, the software can keep track of cumulative data over a work period by accumulating specified events. Thus, it is capable of automatically assessing various definitions of cumulative exposure (cumulative peak events, cumulative average events, etc.).

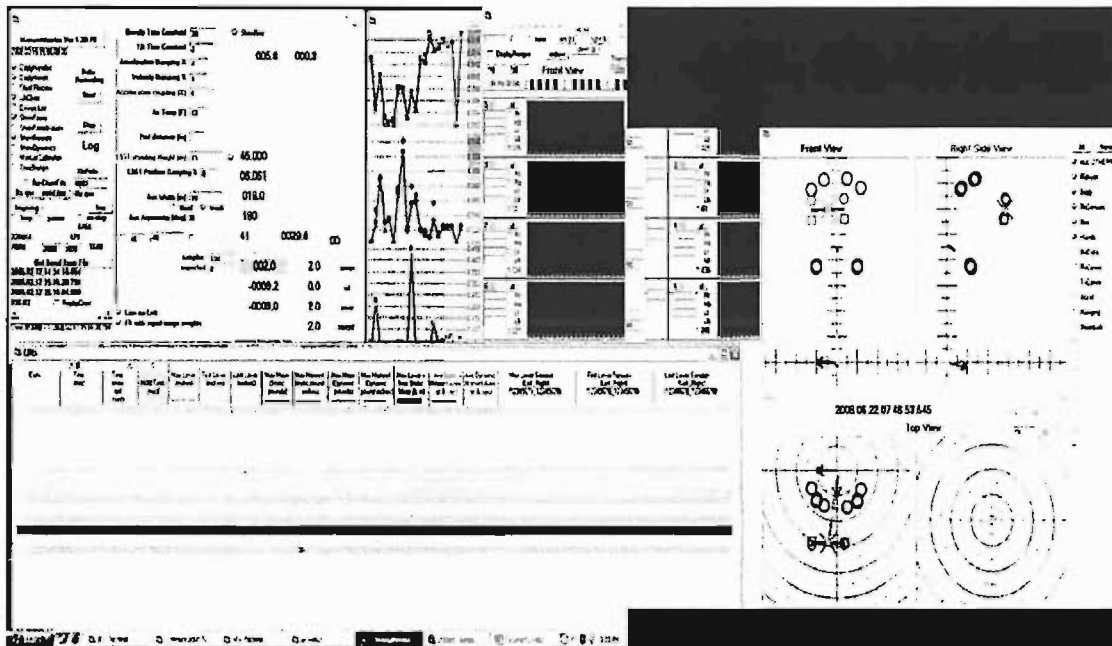


Figure 2-6. Example of a software screen designed to assess sonic receiver visibility, individual lift features, and cumulative lift features. The small circles in the right hand portion of the screen indicate the receiver locations from a front, side, and top view. The green and red dots indicate the target transmitter on the right and left hand respectively.

[illegible]

Figure 2-7. Each line represents the chosen events associated with an individual lift. This feature permits one to efficiently collect information in the field without having to manually partition the data for processing.

2.2.6 Receiver “Vision” Optimization

Placements of the sonic receivers on the backpack frame are critical for optimal triangulation of the target (box) of interest. Two techniques were used to determine the optimal locations of the eight receivers on both the prototype moment arm tracking system and the second generation METS. First, given the cone of vision of the receivers (90 degrees) the field of view was estimated graphically (Figure 2-8) by working backwards from the desired sample space so that the sample space could be “seen” by at least three receivers. Second, a process of systematic testing and comparison with a laboratory based magnetic tracking system (validation testing - next section) was employed where receiver configurations were iteratively altered based upon system performance on more and more rigorous realistic test conditions. Over the course of this project, 9 configurations were assessed with the prototype moment arm tracking system (prototype), and 29 different configurations were studied for the second generation METS.

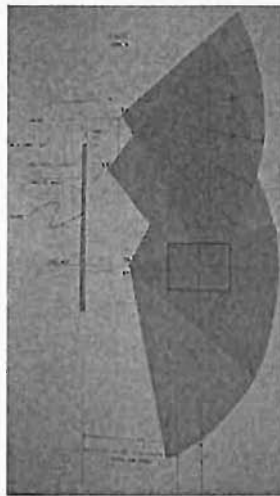


Figure 2-8. Graphical representation of receiver vision space

With 38 different configurations, there were far too many adjustments made than can practically be described here. However, adjustments generally consisted of several general types of modifications. First, originally receivers were placed on the backpack frame as well as on the backpack belts. However, belt movement during dynamic lifts resulted in unacceptable errors. Thus, all receivers were fixed to the backpack frame. Second, accuracy of the METS improved when all 8 receivers were not fixed to the same plane. Thus, in the final configurations the upper receivers were placed on a hoop that extends from the backpack frame forward. In addition, the lower receivers were placed on extender springs to offset them from the backpack frame. Third, specific visibility was adjusted in the various configurations by slightly varying the viewing angle of the various receivers on successive configuration iterations. Finally, software changes permitted receiver distance to change through filtering.

2.2.7 System Validation and Testing

An iterative process was adopted in order to bring the system to within intended specifications for monitoring moment arm distances (an AAE of less than 2.5 inches, thereby greatly improving upon human measured moment arms). In all of these tests a

magnetic motion capture system (The Motion Monitor™) was employed to evaluate the sonic METS' measurements. The iterative process compared the moment arm distances as a function of several conditions that consisted of: 1) static location of the target and the upright backpack system, 2) asymmetric location of a target relative to the backpack system, 3) system backpack angle calculation, 4) backpack flexion angles relative to the target, 5) asymmetric movement of a target, 6) full dynamic motion of the backpack system and motion of the target, and 7) prediction of vertical load location. The data of system validation are shown in the Results section.

2.3 Prospective Field Study

2.3.1 Experimental Design

This was a prospective study which involved 888 manual materials handling workers on 50 jobs in 21 distribution centers. The study used jobs as the unit of analysis. For each of the jobs we sampled, we examined physical exposure and health effects. In order to characterize the **physical exposures**, we monitored continuous dynamic load moment using the METS for up to 4 hours in up to five individuals performing each job. Exposure measurements were taken on 195 distribution center workers. In order to assess **health effects** in each of the jobs sampled, we used quantitative Clinical Lumbar Motion Monitor functional performance test as well as standardized symptom and psychosocial questionnaires. CLMM and survey data were obtained from participants at baseline and 6-14 months follow-ups. There were initially a total of 888 participants at baseline and 451 of them stayed on the same job at follow-up. Low back injury rate for the past three years was also collected for each job from the company's record. The data were evaluated using CART and logistic regression models to determine which physical exposure, psychosocial, and individual factors were predictive of the health outcomes. Once these relationships were developed, proxy measures were identified that can characterize risk using a simplified approach that can be easily implemented by practitioners who design and/or evaluate repetitive lifting tasks.

2.3.2 Site Identification Process

The sites were comprised of distribution organizations in which employees perform repetitive material handling tasks throughout the day. We have selected to focus this work on distribution center workers for the following reasons:

1. They have been under-represented in recent epidemiological studies investigating factors responsible for low back disorders. Employment data from the Bureau of Labor Statistics indicate that jobs in manufacturing decreased from 12.6 million to 10.5 million between 1999 and 2003. During the same recessionary period the number of distribution jobs remained relatively constant, declining from 9.5 million to 9.4 million jobs. Thus, as jobs are shifting from manufacturing the need to study back injury risk in distribution jobs is becoming even more important.
2. There is a range of injury rates across distribution facilities. Figure 2-9 shows the back injury and turnover rates encountered by one of the PIs (S.L.) in a recent back

injury training intervention study that used distribution center employees. These data are only for those who perform lifting repetitive lifting tasks.

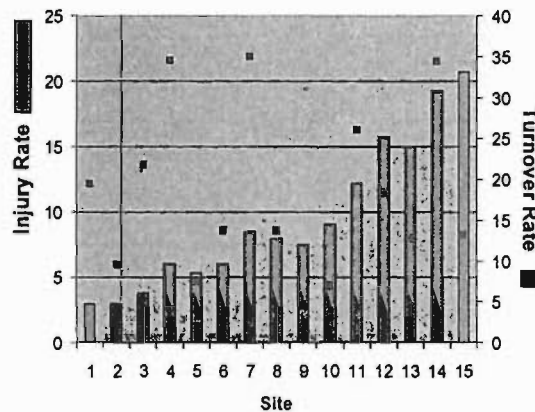


Figure 2-9. Back injuries per 100 full time workers (bars) and turnover rates (squares) for individuals performing distribution jobs requiring repetitive lifting.

3. Unlike manufacturing, most of the manual work in distribution centers is spread across a relatively small number of jobs, each with many employees. This allows the analysis of individual characteristics, for example anthropometric variables, to be evaluated for their contribution to the outcome variables.
4. Our previous work with distribution centers has shown there is a range of low back disorder risk that can be found across distribution facilities (see Sample Size Calculations below).
5. Distribution center workers are exposed to constantly changing lifting conditions, thereby making it extremely difficult to accurately assess low back disorder risk using existing measures.
6. Biomechanically, the design of distribution jobs has remained largely unchanged. Thus, health outcome data should be consistent with current work exposures.

Sites were selected based upon location, quality of injury reports, and willingness on the part of management to work with the study group. Based on our experience and contacts we were targeting grocery, automotive parts, cosmetics, clothing, general retail, consumer electronics distribution centers for participation in the study. All of these sites have people performing repetitive lifting jobs.

Given the similarity of “jobs” within distribution centers, jobs were differentiated based upon the department (or section) if people did not float from one department to another. For example a grocery distribution operation may have three to four jobs, depending upon how orders are distributed. Usually employees “pick” in dry groceries, produce, frozen foods, or boxed meats. Hence, a grocery facility with these four areas would potentially contribute four jobs to the study. In other general merchandise distribution centers, where employees potentially pick any item in the warehouse, there may be only one picking or selecting job defined for the facility (albeit with many employees). However, often these facilities have people manually loading and/or unloading trucks.

2.3.3 Sample Size Calculations

Two basic analyses were considered in carrying out sample size calculations. In a “discrete” analysis, we took two risk groups, high vs. low, and “high” and “low” values of the predictor, say load moment, from which we made a 2 x 2 contingency table. Then we need to know how many observations are needed to have adequate power to test whether the odds ratio (OR) is significantly different from 1. For a baseline probability of .2 (probability a job is high-risk given low LM), a true odds ratio of 3, $\alpha = .05$, and $\beta = .2$ (power = .8), the required sample size is 23 jobs per each of the risk groups, or a total of 46 jobs. Power and sample size calculations were performed using the PASS 6.0 software.

Within this observational prospective study, two principal types of data were collected: exposure data and outcome data. For a job to be considered it must meet the inclusion/exclusion criteria described in Table 2-2. In each job sampled there must be enough individuals working in the job so that we obtain good estimates of health outcomes, psychosocial exposure measures, and the relevant individual characteristics that could be pooled to represent job characteristics. Hence, we only considered jobs if they had at least 3 or more full-time workers, defined as those working 35 or more hours per week. In each job we attempted to recruit all the employees to participate in our survey and CLMM assessment (low back impairment status).

Table 2-2. Inclusion and exclusion criteria for jobs in the sample.

Inclusion	Exclusion
▫ More than 3 workers	▫ Handle items that cannot be lifted with force measuring handles (e.g. > 20% of items)
▫ Discrete job title for injury reporting purposes	▫ Drive equipment in a seated posture
▫ Handle items that can be lifted using the instrumented handles.	▫ Ambient temperature less than 30 degrees F

Overall, a total of 21 different distribution centers were recruited in the study. There are six types of products handled by the employees of the distribution centers. A total of 50 jobs were identified within these facilities. Table 2-3 summarizes the types of products handled and the number of jobs sampled from each type of distribution centers.

Table 2-3. The number of jobs sampled by distributed product type.

Product Type	Number of sites	Number of Jobs
Grocery	3	11
Food Products	4	5
General Merchandise	4	13
Auto Parts	2	7
Clothing	4	10

Other: Hair care products, paper, hardware, furniture	4	4
Total	21	50

2.3.4 Exposure Data Sampling Process

Within each identified job up to 5 volunteers were recruited for the load moment exposure measurements (this number may be less if only a small number of employees performed the job or if the volunteer rate was low). These participants must sign the informed consent documentation and were compensated for their participation with gift cards from area merchants. Each employee was monitored for up to four hours which, given normal productivity requirements, included several hundred lifts per participant. In some cases shorter sampling periods were used if the full range of exposure data that were representative of the job could be obtained with shorter sampling periods. We worked with the facility management to help us identify “typical” workloads for each job when designing our sampling strategy at the site.

Load moment exposure data were obtained using the METS instrumentation we have developed and described extensively in the report. This instrumentation is capable of tracking the load moment, both static and dynamic, from each lift a participant makes during his or her normal work performance. The instrumentation is essentially an automated data collection system that continuously monitors and records, 3D hand locations relative to the L5/S1, the instantaneous load, the orientation of the torso, and the timing of lifting events. As part of the modularization process that we went through in the development phase, we have been able to put together additional units so that five employees can be sampled at the same time. Participants were recruited from the workers participating in the health effects component of the study (see below). Each health effects participant was shown a poster describing the work-sampling process and asked if they would be interested in volunteering for the work-sampling portion of the study. Names were randomly selected from the pool of interested persons for each job to be sampled.

Each volunteer was brought in to review and sign informed consent documents and be instrumented with the METS. This consent and set-up process took approximately 20 minutes. Once a participant was ready to return to work they were followed by a member of the research team who would primarily be observing unit integrity, keeping track of the type of work performed, and if there was any situations that would introduce irregularities into the data stream being recorded on the units flash memory card. Thus, with five units we were capable of sampling one job per day.

We asked the employee and the management that the work be done at a normal pace. For example, if the employee normally worked on a productivity standard we asked for that pace to be maintained. This is necessary to obtain accurate temporal data regarding the periods of time between moment exposures and accurate cumulative moment exposure data.

The METS provided continuous extensive load moment exposure data throughout the observation period. A myriad of measures were derived from this data stream including cumulative static and dynamic load moment exposure distributions. For each distribution, several parameters describing the distribution were extracted which allowed many different ways of assessing relationships describing LBD risk. In addition, all the parameters usually recorded for use in the NIOSH lifting equation, including the height of the hands at the beginning and end of the lift, and the degree of asymmetry relative to the pelvis, were obtained.

Data were continuously collected using the built-in microprocessor and stored on memory flash cards for later analysis. The data processing programs, by using the load measurement handles can identify lift initiation and termination points and therefore can be used to identify the intervals of time during which lifting is occurring and the inter-lift (rest) periods.

2.3.5 Health Effects Data and Psychosocial Measures

Injury data. Each facility was asked to provide OSHA 300 records and first aid reports. At the same time the facilities were asked to supply the average hours per week worked by personnel in each of the jobs monitored. For each identified job, injury rates were calculated and normalized to per 200,000 hours of exposure (1200k). We asked that these data be provided by the participating organizations with the employee names removed and replaced with a job identifying code.

Low back functional impairment. In order to overcome the limitations and potential biases of injury reporting systems, all of the prospectively monitored employees (up to 45 subjects per job) were recruited to participate in an assessment of low back functional performance using the revised Clinical Lumbar Motion Monitor protocol (Ferguson & Marras, 2004). All employees participating in this aspect of the study were required to sign informed consent documentation. The assessments were conducted at the baseline of the prospective monitoring period and the follow-up. This assessment provided objective data describing the back's functionality that was not affected by discrepancies in the injury recording process. The model underlying this analysis has been shown to have excellent sensitivity (90%) and specificity (92%) for correctly differentiate those with and without back pain (Marras, Ferguson, Gupta, Bose, Parnianpour, Kim, & Crowell, 1999; Marras, Parnianpour, Ferguson, Kim, Crowell, Bose, & Simon, 1995). By comparing each employee's function with that in the database of normal controls, the model is able to quantify the overall probability the measured employee would be part of the normal population yielding a measure of the degree of impairment. The assessment was comprised of 6 individual tasks, an overall "Probability of Normal" or Pn score is determined as well as range of motion, velocity and acceleration for each task. The functional performance output also has probability of sincere effort score, which ensures high quality data. Thus, the analysis provides an overall score, as well as scores for specific movements. This was an important covariate given that we were sampling existing work forces that may have already experienced some degree of low back disorder. Employees participating in the protocol were compensated with a hat or t-shirt for their participation.

Symptom and psychosocial assessment survey. Each individual participating in the Low Back Functional Impairment assessment was asked to fill out a short survey that assessed their current low back pain experience. The survey was comprised of items extracted from the NIOSH assessment instrument that is being used by other members of the Consortium. This survey, which was comprised of 31 items, was administered to each participant during both the initial and follow-up functional impairment assessments. Some of the psychosocial items may be used as exposure measures in the analyses. A copy of the survey has been included in the Appendix A-1.

Follow-up measurements. The same low back functional assessment and questionnaire was administered at the follow-up evaluation. The follow-up evaluation was performed 6 and 14 months after the baseline assessment.

2.3.6 Data Analysis

To address the question of what constitutes a safe moment exposure, we put together a database that contains the load moment and duty cycle data from repetitive material handling jobs. From this database models were developed that allow the relationship between load moment exposure parameters and injury to be defined. These data were tied to outcome data, for example injury reports and Pn score derived from the clinical functional assessment using the CLMM. With these data models were developed that allow us to determine the safe load moment / duty cycle exposures.

For analysis purposes all injury data were normalized to an exposure period of 200,000 person-hours. This converted the incidence data into an injury rate for each job sampled. The outcome data from the survey and the low back functionality tests (percentages) were averaged across employees in the individual jobs. In addition, parameters describing the distribution of scores were indicative of the level of impairment experienced by employees within each job sampled.

Descriptive statistics were computed for all variables, and distribution plots were generated for the load moment exposure variables. Univariate logistic regression models were developed for incident rate and change in low back functional measure (Pn). Significant variables were identified through the univariate analysis to screen variables for further analysis. Odds ratios and correlation coefficients were calculated for each predictor individually.

The overall goals were to find the best set of load moment and duty cycle variables which predict incident rate and low back disability measured with change in low back function (Pn), and to give functions for the relationship between the predictors and outcome. To avoid over-specified models, no more than five predictors were allowed in a model, following the rule that the number of predictors should be no more than 10 percent the number of observations. CART software was used as a variable selection tool for building the final statistical models.

Given that the ultimate goal of this project is to provide guidance to industry regarding safe moment exposure levels, the final product of this work will be a proxy that incorporates the essence of the identified models in a simplified format. The goal here is to present the models in such a way that an individual with limited computational skill and simple instrumentation can evaluate the lifting conditions within his or her facility. This specific aim was achieved by a multi-stage approach. First, the previous analysis indicated which measures provide the most precise measure of LBD risk. This served as the “gold standard” by which other measures were judged. Second, we examined our database for easily obtained measures that did not require sophisticated instrumentation. Third, we examined the correlations between these easily obtained measures and our gold standard. Fourth, we found cut-points using CART and developed logistic regression models using these surrogate measures. Finally, we employed logistic regression cross-validation techniques using our database to evaluate the sensitivity and specificity of the simplified models.

3. Results

3.1 Preliminary modeling based on an existing industrial exposure database

Table 3-1 shows the univariate logistic regression analysis of the variables in the existing manufacturing exposure database when they were treated as continuous variables. Low risk was defined as 0 incidence of low back disorder and no turnover, whereas high risk was defined as 12 or more incidence of low back disorder per 200,000 hours of exposure. The odds ratios for job being in the high risk group of low back disorder for the univariate analysis were all less than 1.5. However, when the variables were dichotomized based on CART, as shown in Table 3-2, many load moment variables had high odds ratios. For example, mean box weight, peak box weight, mean moment, and peak moment all had very high odds ratios. There were also many dynamic trunk motion variables showing high odds ratios, such as sagittal range of motion, lateral range of motion, sagittal velocity, and twisting velocity. These odds ratios may be high because typically odds ratios are used to predict rare diseases however low back incidence is not a rare disease. These results were consistent with the previous study (Marras, Lavender, Leurgans, Rajulu, Allread, Fathallah, & Ferguson, 1993) based on the same database.

Table 3-3 presents the original logistic regression model based on the existing industrial exposure database. The sensitivity for this model was 72% and the specificity was 77%. When using dichotomized variables based on the CART software to same variables as the original model, as shown in Table 3-4, the sensitivity of the model was 73%, which did not change much. But the specificity has increased from 77% to 86%, which means that there is less chance to misclassify the low risk jobs as high risk jobs. This comparison indicates that CART can help improve the performance of the model. Instead of using odds ratio we are using probabilities to evaluate the risk. In a multivariate model with 0 and 1 predictors, the odds ratio may be difficult to interpret because the same odds ratio can be found for very different odds, using the probabilities eliminates this problem. Therefore, Table 3-5 was created to show the probabilities for all combinations of zero and one for all five variables in the dichotomized model. If all five variables are less than the cut-points in Table 3-4 then the probability of the job being high risk is 0.0250. If the only variable exceeding the cut-point is peak moment then the probability is 0.5730. This illustrates the importance of peak moment in the model. Among the combinations of two variables exceeding the cut-point, the highest probability (0.8593) occurs with peak moment and sagittal flexion exceeding the cut-point. Any other measure combined with peak moment has a probability between 0.7113 and 0.8593. This again illustrates the importance of peak moment as well as how much the probability increases when combined with any other variable compared to peak moment by itself (0.5730). Among the combinations with three variables exceeding the cut-point, the combination with peak moment, lift rate and sagittal flexion has the highest probability among the three variables models with a probability of 0.9472. If all five variables in the model exceed the cut-points in Table 3-4 then the probability of the job being high risk is 0.9863.

Table 3-1. Univariate logistic regression of variables in the existing industrial exposure database. Variables were treated as continuous variables.

CONTINUOUS			Odds Ratio	95% Confidence			Probability
Variable Name	beta	STD	Point Estimate	Interval	Sensitivity	Specificity	Level
Lift rate	0.00005	0.000007	1.00	1.00-1.00	0	99	0.46
Start Height	-0.00675	0.000085	0.99	0.993-0.993	36	66	0.46
Finish Height	-0.0187	0.00009	0.981	0.981-0.982	69	49	0.42
Load Distance	-0.0087	0.0001	0.991	0.991-0.992	49	49	0.46
Mean Box Weight	0.1495	0.0004	1.161	1.16-1.162	68	79	0.38
Mean Moment Arm	0.0078	0.00013	1.008	1.008-1.008	60	52	0.44
Mean Moment	0.0313	0.000075	1.032	1.032-1.032	60	84	0.44
Peak Box Weight	0.1326	0.00031	1.142	1.141-1.142	75	75	0.34
Peak Moment Arm	0.017	0.0001	1.017	1.017-1.017	70	52	0.4
Peak Moment	0.0254	0.00005	1.026	1.026-1.026	74	78	0.34
Mean lateral position left	-0.0185	0.0003	0.982	0.981-0.982	35	66	0.46
Mean lateral position right	-0.051	0.0003	0.95	0.95-0.951	55	40	0.46
Mean sagittal position extension	0.0416	0.0002	1.042	1.042-1.043	32	61	0.48
Mean sagittal position flexion	0.0349	0.0002	1.035	1.035-1.036	37	75	0.48
Mean twisting position left	0.0332	0.00031	1.034	1.033-1.034	40	53	0.46
Mean twisting position right	0.0187	0.0003	1.019	1.018-1.019	57	39	0.44
Mean lateral range of motion	-0.0141	0.0002	0.986	0.986-0.986	64	25	0.44
Mean sagittal range of motion	0.0327	0.00019	1.033	1.033-1.034	39	73	0.46
Mean twisting range of motion	-0.0148	0.0003	0.985	0.985-0.986	34	54	0.46
Mean Lateral Average Velocity	0.2199	0.00087	1.246	1.244-1.248	61	70	0.42
Mean Sagittal Average Velocity	0.3033	0.00082	1.354	1.352-1.357	68	64	0.36
Mean Twisting Average Velocity	0.1682	0.0007	1.183	1.182-1.185	52	58	0.4
Mean Lateral Maximum Velocity	0.0266	0.0002	1.027	1.027-1.027	57	59	0.44
Mean Sagittal Maximum Velocity	0.037	0.00014	1.038	1.037-1.038	55	59	0.4
Mean Twisting Maximum Velocity	0.0072	0.0001	1.007	1.007-1.008	49	45	0.44
Mean Lateral Acceleration	0.0042	0.00003	1.0004	1.004-1.004	50	58	0.44
Mean Lateral Deceleration	-0.0038	0.00003	0.996	0.996-0.996	50	58	0.44
Mean Sagittal Acceleration	0.0071	0.00003	1.007	1.007-1.007	55	64	0.4
Mean Sagittal Deceleration	-0.0073	0.00003	0.993	0.993-0.993	42	70	0.44
Mean Twisting Acceleration	0.0013	0.00002	1.001	1.001-1.001	29	74	0.46
Mean Twisting Deceleration	-0.001	0.00002	0.999	0.999-0.999	0.45	0.4	0.44

Table 3-1. Univariate logistic regression of variables in the existing industrial exposure database. Variables were treated as continuous variables. (continued)

CONTINUOUS							
Variable Name	beta	STD	Odds Ratio Point Estimate	95% Confidence Interval	Sensitivity	Specificity	Probability Level
Peak lateral position left	0.0099	0.0003	1.01	1.009-1.011	68	21	0.44
Peak lateral position right	-0.0037	0.00028	0.996	0.996-0.997	74	2.4	0.44
Peak sagittal position extension	0.0561	0.00022	1.058	1.057-1.058	48	61	0.46
Peak sagittal position flexion	0.0391	0.00012	1.04	1.04-1.04	68	59	0.4
Peak twisting position left	0.0758	0.00033	1.079	1.078-1.079	59	55	0.44
Peak twisting position right	0.0523	0.0003	1.054	1.053-1.054	46	69	0.46
Peak lateral range of motion	0.0071	0.00018	1.007	1.007-1.007	24	79	0.46
Peak sagittal range of motion	0.0405	0.00014	1.041	1.041-1.042	54	64	0.42
Peak twisting range of motion	0.0298	0.00022	1.03	1.03-1.031	52	58	0.44
Peak Lateral Average Velocity	0.2184	0.0006	1.244	1.242-1.246	56	79	0.46
Peak Sagittal Average Velocity	0.1735	0.0005	1.189	1.188-1.191	60	79	0.4
Peak Twisting Average Velocity	0.1511	0.00049	1.163	1.162-1.64	45	84	0.46
Peak Lateral Maximum Velocity	0.0426	0.00015	1.044	1.043-1.044	48	79	0.48
Peak Sagittal Maximum Velocity	0.0204	0.00007	1.021	1.020-1.021	59	67	0.4
Peak Twisting Maximum Velocity	0.0203	0.0001	1.02	1.020-1.021	39	81	0.48
Peak Lateral Acceleration	0.0054	0.00002	1.005	1.005-1.005	57	64	0.42
Peak Lateral Deceleration	0.0017	0.00003	1.002	1.002-1.002	31	63	0.46
Peak Sagittal Acceleration	0.0036	0.00001	1.004	1.004-1.004	57	67	0.4
Peak Sagittal Deceleration	-0.0035	0.00004	0.997	0.996-0.997	40	54	0.44
Peak Twisting Acceleration	0.0024	0.00001	1.002	1.002-1.002	51	58	0.42
Peak Twisting Deceleration	0.0014	0.00003	1.001	1.001-1.001	41	58	0.46

Table 3-2. Univariate analysis of variables in the existing industrial exposure database. Variables were dichotomized based on CART.

Variable Name	Cut point	beta	STD	Odds Ratio Point Estimate	95% Confidence Interval	Sensitivity	Specificity	Probability Level
Lift rate	119	0.5944	0.0041	1.81	1.79-1.83	46	78	0.50
Start Height	92.6	-0.4712	0.0043	0.624	0.619-0.630	37	72	0.44
Finish Height	116.4	-1.1149	0.004	0.328	0.325-0.331	75	48	0.44
Load Distance	59.5	-1.67	0.0151	0.188	0.183-0.194	98	6.5	0.44
Mean box weight	1.04	3.809	0.0084	45.1	44.4-45.9	92	55	0.50
Mean Moment Arm	59.7	1.029	0.0044	2.799	2.774-2.823	71	55	0.50
Mean moment	14.6	2.93	0.005	18.7	18.59-18.97	78	74	0.44
Peak box weight	1.48	3.04	0.0057	20.86	20.63-21.09	86	60	0.44
Peak Moment Arm	62.2	1.322	0.0046	3.75	3.718-3.786	78	52	0.44
Peak moment	18.5	3.045	0.0054	21.02	20.79-21.23	81	73	0.44
Mean lateral position left	-7.9	-0.451	0.0043	0.958	0.948-0.964	100	0	0.42
Mean lateral position right	15.9	-1.345	0.0066	0.26	0.257-0.264	89	13	0.44
Mean sagittal position extension	-28.5	-2.803	0.0156	0.061	0.059-0.063	98	10	0.44
Mean sagittal position flexion	-2.2	1.16	0.0043	3.196	3.169-3.223	71	45	0.44
Mean twisting position left	-7.6	-0.4751	0.0043	0.622	0.617-0.627	66	27	0.44
Mean twisting position right	12	1.33	0.0063	3.79	3.74-3.83	23	90	0.44
Mean lateral range of motion	4.6	16.1	17.9	***	***	***	***	***
Mean sagittal range of motion	6.5	2.43	0.0101	11.45	11.23-11.69	96	16	0.44
Mean twisting range of motion	15.4	-0.7624	0.0042	0.467	0.463-0.470	72	31	0.44
Mean Lateral Average Velocity	5.9	1.179	0.0042	3.25	3.22-3.28	62	68	0.50
Mean Sagittal Average Velocity	6.5	1.65	0.0045	5.23	5.18-5.28	46	84	0.50
Mean Twisting Average Velocity	7.5	2.03	0.0065	7.58	7.48-7.68	29	94	0.50
Mean Lateral Maximum Velocity	32.1	0.9142	0.0044	2.49	2.47-2.52	40	82	0.50
Mean Sagittal Maximum Velocity	12.3	2.368	0.0099	10.67	10.46-10.88	96	18	0.44
Mean Twisting Maximum Velocity	33.6	0.8543	0.0044	2.35	2.33-2.37	33	78	0.50
Mean Lateral Acceleration	159.6	0.8605	0.0042	2.36	2.34-2.38	62	56	0.44
Mean Lateral Deceleration	-116	1.25	0.0051	3.49	3.46-3.53	83	35	0.44
Mean Sagittal Acceleration	132	1.55	0.0043	4.71	4.67-4.75	65	58	0.44
Mean Sagittal Deceleration	-72.6	2.28	0.0093	9.73	9.55-9.91	96	19	0.50
Mean Twisting Acceleration	222	1.01	0.0044	2.76	2.74-2.78	35	77	0.50
Mean Twisting Deceleration	-116	-0.3595	0.0047	0.698	0.692-0.704	36	71	0.46

Table 3-2. Univariate analysis of variables in the existing industrial exposure database. Variables were dichotomized based on CART.
(continued)

Variable Name	Cut point	beta	STD	Odds Ratio Point Estimate	95% Confidence Interval	Sensitivity	Specificity	Probability Level
Peak lateral position left	9.1	1.398	0.0084	4.05	3.98-4.11	96	3	0.44
Peak lateral position right	9.7	0.536	0.0051	1.71	1.69-1.73	78	31	0.46
Peak sagittal position extension	-8.7	-1.26	0.0042	0.283	0.281-0.286	50	60	0.50
Peak sagittal position flexion	2.26	1.495	0.0049	4.46	4.42-4.50	81	40	0.50
Peak twisting position left	1.6	-1.511	0.0048	0.221	0.219-0.223	37	81	0.50
Peak twisting position right	16.6	1.6426	0.0052	5.17	5.12-5.22	35	86	0.50
Peak lateral range of motion	53.3	-16.07	19.3	***	***	***	***	***
Peak sagittal range of motion	36	1.237	0.0045	3.45	3.42-3.48	37	79	0.50
Peak twisting range of motion	36.6	3.03	0.0184	20.74	20.01-21.50	10	99	0.50
Peak Lateral Average Velocity	9.6	1.147	0.0042	3.15	3.12-3.17	52	81	0.50
Peak Sagittal Average Velocity	10.3	2.03	0.005	7.64	7.56-7.72	40	91	0.50
Peak Twisting Average Velocity	9.8	2.11	0.005	8.24	8.15-8.33	37	91	0.50
Peak Lateral Maximum Velocity	39.7	1.31	0.0042	3.69	3.66-3.72	60	68	0.50
Peak Sagittal Maximum Velocity	38.6	1.47	0.0042	4.38	4.34-4.41	61	65	0.50
Peak Twisting Maximum Velocity	53.4	1.22	0.0045	3.39	3.36-3.42	37	83	0.50
Peak Lateral Acceleration	215	1.0107	0.0045	2.75	2.72-2.77	70	46	0.44
Peak Lateral Deceleration	-118	0.3175	0.0041	1.37	1.36-1.38	37	65	0.44
Peak Sagittal Acceleration	184	1.629	0.0047	5.10	5.05-5.15	74	54	0.44
Peak Sagittal Deceleration	-132	1.021	0.0050	2.78	2.75-2.80	22	88	0.44
Peak Twisting Acceleration	321	1.136	0.0042	3.12	3.09-3.14	39	71	0.44
Peak Twisting Deceleration	-188	-0.6355	0.0063	0.53	0.52-0.54	90	14	0.44

*** indicates results were not interpretable

Table 3-3. Original logistic regression model based on the existing industrial exposure database.

Variable	Beta	Mean		Point estimate odds ratio	95% confidence interval		Sensitivity	Specificity
		high risk jobs	low risk jobs					
Lift rate	0.0014	187	183	1.001	1.001	1.001	72	77
Peak twisting average velocity	0.061	8.71	5.44	1.063	1.062	1.064		
Peak moment	0.0242	86.9	22.2	1.025	1.024	1.025		
Peak sagittal flexion	0.0196	20.7	8.7	1.019	1.019	1.020		
Peak lateral maximum velocity	0.0363	46.6	36.7	1.037	1.036	1.037		

Table 3-4. CART-assisted logistic regression model based on the existing industrial exposure database (using the same variables as the original model).

Variable	Beta	CART cut points	St Error	Wald Score	P-value	Sensitivity	Specificity
Lift rate	1.08	119	0.0062	30282	0.0001	73	86
Peak twisting average velocity	0.7809	8.76	0.0061	16286	0.0001		
Peak moment	3.05	18.46	0.0062	243706	0.0001		
Peak sagittal flexion	1.51	9.05	0.0064	55944	0.0001		
Peak lateral maximum velocity	0.6078	45.3	0.0067	8178	0.0001		

Table 3-5. Probability of the job being high risk using the dichotomized LMM risk model for all combinations of predictors.

Lift Rate	Peak Twisting Average Velocity	Peak Moment	Peak Sagittal Flexion	Peak Lateral Maximum Velocity	Probability (High-risk)
0	0	0	0	0	0.0250
1	0	0	0	0	0.0699
0	1	0	0	0	0.0529
0	0	1	0	0	0.5730
0	0	0	1	0	0.1043
0	0	0	0	1	0.0449
1	1	0	0	0	0.1410
1	0	1	0	0	0.7977
1	0	0	1	0	0.2550
1	0	0	0	1	0.1213
0	1	1	0	0	0.7455
0	1	0	1	0	0.2027
0	1	0	0	1	0.0930
0	0	1	1	0	0.8593
0	0	1	0	1	0.7113
0	0	0	1	1	0.1762
1	1	1	0	0	0.8960
1	1	0	1	0	0.4277
1	1	0	0	1	0.2316
1	0	1	1	0	0.9472
1	0	1	0	1	0.8786
1	0	0	1	1	0.3859
0	1	1	1	0	0.9302
0	1	1	0	1	0.8432
0	1	0	1	1	0.3183
0	0	1	1	1	0.9181
1	1	1	1	0	0.9751
1	1	1	0	1	0.9405
1	1	0	1	1	0.5784
1	0	1	1	1	0.9705
0	1	1	1	1	0.9608
1	1	1	1	1	0.9863

3.2 Moment Exposure Tracking System validation results

3.2.1 Static target location with an upright backpack system

This test compared the system derived moment arm distance with both hand measurements and the magnetic tracking system predictions. Hand measurements employed a series of plum bobs to accurately assess moment arm distance. Combinations of three different target heights, three different moment arm lengths, and three different asymmetries were tested both with and without a person attached to the METS over a total of 54 different test conditions. Figure 3-1 shows the METS mounted to a structure using one of the latest configurations of the receivers. Eleven different combinations of configurations and software were used to test this system.



Figure 3-1. Static validation of one of the latter receiver system configurations.

Results: Over the various configurations AAE varied from 0.9 inches to 3.0 inches. The final configuration (shown in Figure 2-8) yielded an AAE of 0.9 inches with computationally intensive software (see further discussion in section 3.2.8). The AAE changed to 1.6 inches when more computationally efficient software was used to analyze the data. No differences in system visibility or performance were observed with or without a human wearing the METS under these conditions. For the final configuration AAE was generally invariant to target height and moment arm distance.

3.2.2 Asymmetric target location

The objective of this test was to determine the degree to which asymmetry needed to be considered in the receiver vision space when subjects lifted from asymmetric origins and destinations. Twisting during a lift can occur at the hips, the spine, or the shoulders. If twisting occurs primarily in the lower body, the backpack should turn with the upper body and receiver visibility would be expected to be adequate. However, if the subject twists within the backpack at the spine or the shoulders, then the visual field of the METS

relative to the backpack would need to be expanded. In order to test this behavior, a video camera recorded asymmetric lifts from a vantage point directly above the subject. The subject was asked to lift boxes from 6 different asymmetric locations (15, 30, and 45 deg asymmetry clockwise and counterclockwise) as shown in Figure 3-2. Box locations were also placed at two different heights (low and high) off the floor. Dependent variables consisted of the maximum asymmetry angle between the box and the sagittal origin of the backpack.

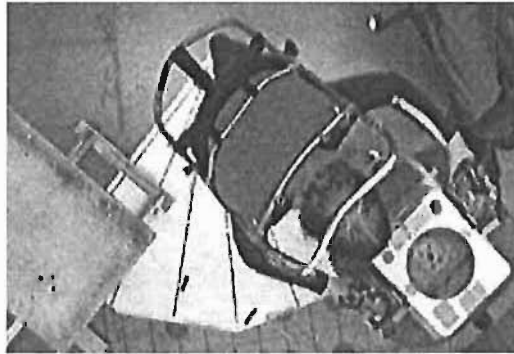


Figure 3-2. Evaluation of asymmetric angle of the box relative to the backpack during asymmetric lifting.

Results: The average asymmetrical deviation among all subjects was 16 degrees with a standard deviation of 9 degrees. However, a trend was also noted for all subjects in that as the testing period progressed, the asymmetric deviations decreased significantly. This indicated that as subjects fatigued they tended to “square up” with the load and twisted less. The observed asymmetric behavior of the subjects could be monitored easily by the METS as it was well within the sonic receivers’ field of view.

3.2.3 System backpack angle calculation

The ultrasonic system tracks the position of a target relative to the backpack upon which the receivers are mounted. However, horizontal moment arm distance is defined as the horizontal distance from the load lifted to the spine. Thus, if a person is lifting while the torso is flexed, the sonic system can locate the target relative to the backpack but the position of the backpack relative to the world must be tracked in order to determine the target location relative to the spine. Hence, accurate assessments of sagittal and lateral backpack angles are crucial to the successful determination of moment arm distance during a lift. In order to validate the backpack angles the processing box that contains the backpack accelerometer system was mounted upon an angular reference frame (Figure 3-3). The magnetic motion capture system described earlier (Motion Monitor™) was also used to measure the angle of the METS accelerometer system. In this manner the backpack angle predictions could be compared to two reference systems.

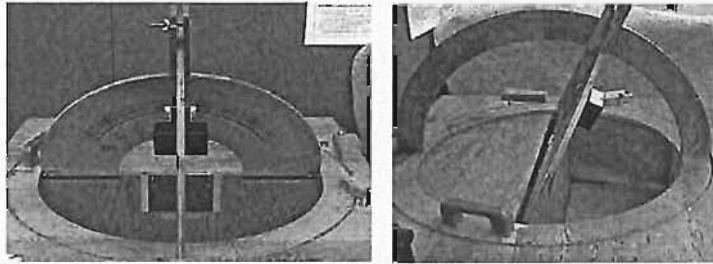


Figure 3-3. Angular reference frame used to validate accelerometer angle in the sagittal and lateral directions.

Results: The results of this assessment are shown in Figure 3-4 for sagittal and lateral bending. The figure indicates that both the magnetic motion capture predictions and the sonic predictions of angle contained erroneous angle predictions in both the sagittal and lateral bending planes. Regression equations were created to correct for these errors and are now used by the system software to predict angle. After the software correction, AAE for both sagittal and lateral bends is now 0.6 degrees.

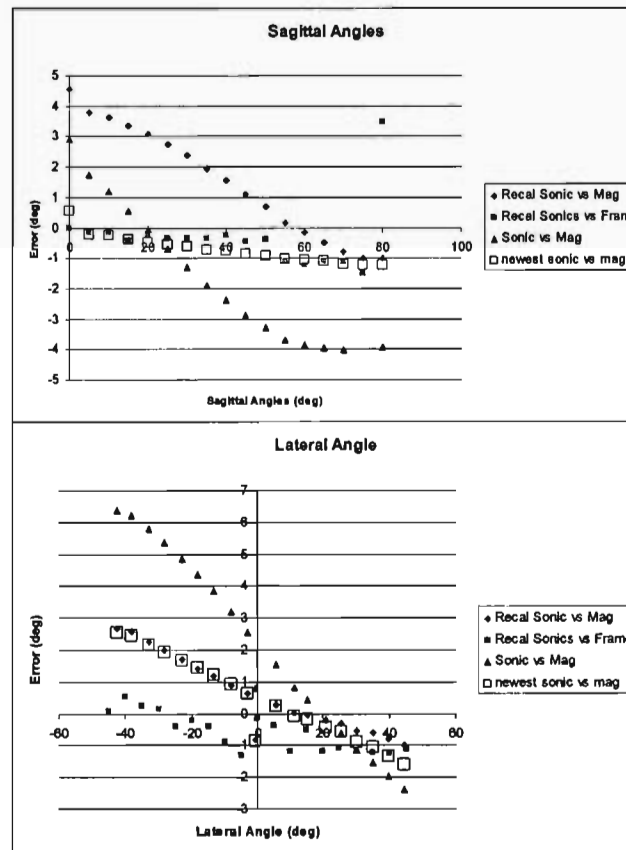


Figure 3-4. Accelerometer system sagittal angle and lateral angle predictions compared to a reference frame and a magnetic motion capture system.

3.2.4 Backpack flexion relative to target location

Once the backpack angles prediction were validated, the moment arm distance predictions needed to be verified through a test in which the backpack was oriented in a series of flexed postures (as would be expected during lifting). The backpack was tested in 10 degree increments over a 90 degree range of flexion. The target box was tested under two conditions: 1) stationary in space while placed at different heights, and 2) moving in a fixed position relative to the backpack. Dependent measures consisted of the AAE between the moment arm distances predicted by the METS and those predicted by the magnetic motion capture system described earlier. Eighteen different configurations were tested in these analyses.

Results: The AAE varied over the configurations from 1.0 to 5.2 inches. The final (optimal) configuration yielded an AAE of 1.4 inches with a standard deviation of 0.5 inches. Under fixed target conditions the AAE was below 1.0 inches.

3.2.5 Asymmetric movement of a target (relative to the backpack)

The next step in the iterative process called for an assessment of the effects of dynamic motion of the target relative to the backpack under changes in target asymmetry and changes in target height. Subjects wore the METS and moved boxes asymmetrically from side to side. The backpack was generally in an upright position during this evaluation but the box origins and destinations varied in vertical height between waist and shoulder height (Figure 3-5). Both the sonic METS and the magnetic motion capture system were used to simultaneously estimate the continuous moment arm distance of the box from the spine over the course of the lift. Dependent measures consisted of AAE as well as the R^2 value describing the amount of dynamic variability accounted for by the two measurement systems. Six different system configurations performed well enough on previous tests to be evaluated under these conditions.



Figure 3-5. Evaluation of moment arm during asymmetric movements of a box.

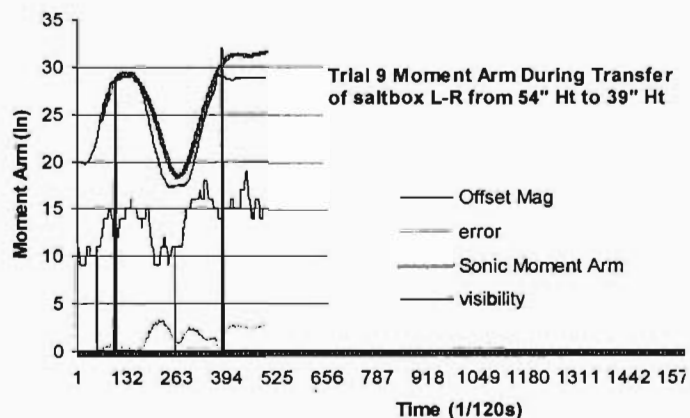


Figure 3-6. Comparison of the sonically derived moment arm to the magnetically derived moment arm over the course of a single lift.

Results: The AAE varied among the configurations from 1.0 inches to 4.6 inches. R^2 values varied from 0.47 to 0.93. The final configuration yielded an AAE of 1.9 inches and an R^2 value of 0.93. Figure 3-6 shows an example of a comparison between the magnetically and sonically derived moment arms for a single test condition.

3.2.6 Fully dynamic backpack and target motion

The ultimate test of the METS involves fully dynamic activities of both the METS backpack system and the target. In this assessment subjects were asked to lift boxes at a normal speed from three different heights (below knee to above shoulders) to a carrying (waist level) position. The sonic METS estimates of moment arm distances were compared with magnetic motion capture system's predictions of moment arms (Figure 3-7). Both AAE and R^2 were used as measures of performance. Only three configurations performed well enough on previous tests were considered for this testing.



Figure 3-7. Fully dynamic test of METS.

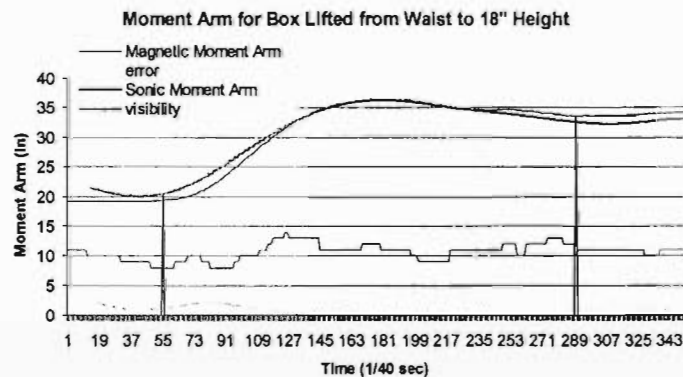


Figure 3-8. An example from the final configuration of how well the METS tracks the moment arm compared to the laboratory-based magnetic tracking system.

Results: All three configurations performed well with excellent tracking of the target. Figure 3-8 shows an example from the final configuration of how well the system tracks the moment arm compared to the laboratory based magnetic tracking system. Overall, AAE varied among the configurations from 1.5 to 1.6 inches. R^2 values varied from average of 0.77 to 0.99. The final configuration yielded an AAE of 1.5 inches and an average R^2 of 0.98.

3.2.7 Prediction of vertical load height

An important aspect of field testing is the ability to monitor other factors that would be useful in assessing risk. One of the objectives of this study was to be able to monitor work characteristics throughout the course of a work period that could enable the evaluation of LBD risk using various assessment methods, which could then be compared

to risk derived from the METS. As part of the NIOSH consortium we would like to evaluate the predictiveness of the revised NIOSH Lifting equation. Many of the revised equation inputs are available from the METS (e.g. horizontal distance, weight, frequency, etc.). However, vertical height of the load was not an original output of the system. We have adjusted the system so that these data could be obtained and this factor could be evaluated. As a test of the METS ability to accurately quantify this parameter, an evaluation was performed to assess the ability of the system to monitor load height from seven known origins to seven known destinations (including asymmetric motion) during a series of lifting tasks. AAE and R^2 measures served as the dependent variables for this assessment. Two system configurations were evaluated.

Results: The results indicated excellent predictions (AAE below 1.3 inches, average R^2 values above 0.90) with both configurations. The final configuration resulted in an AAE of 0.89 inches and an R^2 value of 0.89.

3.2.8 Optimization of system software speed

As discussed earlier, the software performs many functions including several trial and error routines to optimally locate the box in space. The original software designed to perform this task requires approximately 20 minutes of processing in order to evaluate a 5 second lift. Once the hardware issues were solved through the iterative process discussed above, efforts to make the software more efficient were initiated. The goal was to strike a balance between software speed and accuracy of information so that a practical system could be used in the field. Therefore, the best system configurations were used to collect a data set where estimates from the METS were compared with estimates from the magnetic motion capture system, and with estimates obtained using the original processing software. These results were compared with two other software versions (intermediate and fastest) that significantly reduced processing time. Intermediate software was 10 times faster than the original software whereas the fastest software could process a single lift at nearly real time speeds (between one and two times real time).

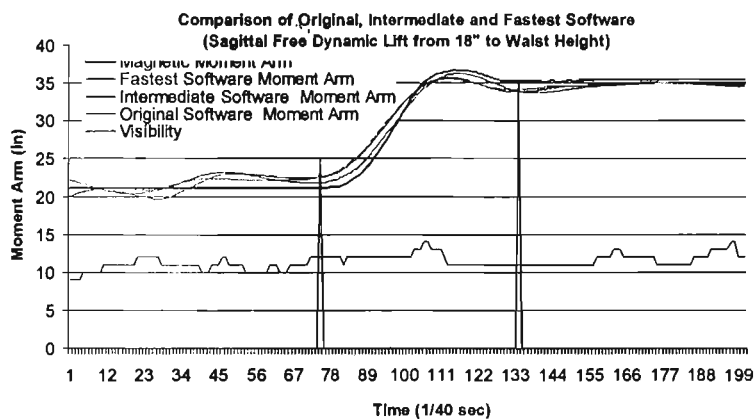


Figure 3-9. Software output comparison for the original, intermediate, and fastest software.

Results: A comparison of the results for these three software versions is shown in Figure 3-9. The results of this analysis indicated that the three versions compare quite favorably with most differences occurring prior to the start of the lift (vertical markers in Figure 3-9). Over the data set, the AAE varied from 1.0 inch for the original software to 1.5 inches for the intermediate speed software, to 2.2 inches for the fastest software. Average R^2 values were excellent for all versions of the software (between 0.94 and 0.96). The fastest software performed poorly on two trial runs (out of 12). When these two trials are eliminated from consideration the AAE became 1.2 inches.

3.3 Prospective field study results

3.3.1 Load moment exposure database

One hundred and ninety five (195) workers in 50 different warehouse jobs participated in the load moment exposure data collection. The average age of the participants was 36.3 (10.9) and 83% of the population was male. A total of 66,854 exertions were recorded, including 44,106 lifts, 18,069 lowers, 2,076 pushes, and 2,603 pulls. Custom software was developed to analyze each of the exertions. A database that contains the load moment exposures, hand position data, and duty cycle parameters was built based on the results of the analyses.

Two hundred and twenty seven (227) variables were included in the load moment exposure database. Table 3-6 is a list of the abbreviated and full names of all the variables. The definitions of these variables can be found in Appendix A-4 (Variable Glossary). The distributions of the load moment exposures, hand position, and duty cycle variables were plotted. Appendix A-2 contains all the distribution plots. The mean and standard deviation of each variable were also calculated. The origin of the coordinate system used to define those variables is at the center of the L5/S1 disc of the lumbar spine. Positive X axis is rightward to the human body. Positive Y direction is forward. Positive Z axis is pointing upward (Figure 3-10). These variables can be classified into several categories.

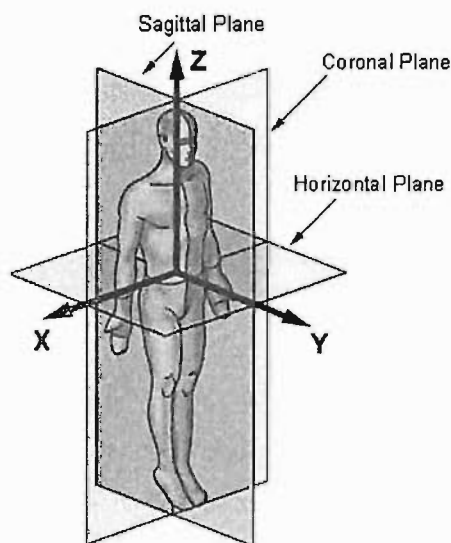


Figure 3-10. The coordinate system used by the Moment Exposure Tracking System.

(Adapted from <http://www.yachigusaryu.com/blog/labels/Technical.html>)

1) Traditional job characteristics:

These variables include box height at start and end, asymmetry at start and end, exertion frequency, exertion duration, duration of non-load exposure. These variables combined with variables from other categories were used to calculate the 1993 NIOSH Recommended Weight Limit (RWL) and Lifting Index (LI).

Our sample contains exertions ranging between 0.5 to 32 seconds in length. Longer durations were associated with longer carries. The average start box height was 0.90m, while the average of the end box height was 1.07m. Both heights were normally distributed. The asymmetry distribution plots (Appendix A-2) show that both start and end asymmetry data were normally distributed as well. They ranged from 0 degree (far right) to 180 degrees (far left). The average exertion frequency was 2.3 lifts/min. The mean RWL was 5.0 ± 2.2 kg and the mean LI was 1.5 ± 1.1 .

2) Box weight, dynamic force, moment arm, and moment

The mean box weight was 55.6 N (≈ 12.5 lbs), with a standard deviation of 35.3 N (≈ 7.9 lbs). The mean of the maximum dynamic Z force was 93.3 N, while the mean of the average dynamic Z force was 54.1 N. The dynamic force in the Y direction (front-back) was also very significant, with a mean of the maximum force being 43.5 N.

The plots of the moment arm variables showed that they were normally distributed (Appendix A-2). The means of the start and end horizontal (XY) moment arms were 0.45 m and 0.42 m, respectively. The mean of the maximum horizontal (XY) moment arm was 0.51m, while the maximum 3-D resultant moment arm averaged 0.59 m.

Several moment variables were developed using the combination of box weight (static) or dynamic force and lateral (X), anterior (Y), or vertical (Z) moment arms. Figure 3-11

shows the comparison between the static moment variables and their dynamic counterparts. The dynamic moments are all greater than the static moments. The horizontal (XY) dynamic moment is 22.9% greater than the static horizontal (XY) moment. This increase is mostly due to the forward bending component (X-axis) of the dynamic moment, which is 22.7% greater than the static moment. The lateral bending component (Y-axis) of the dynamic moment is slightly greater (12.1%) than the static one.

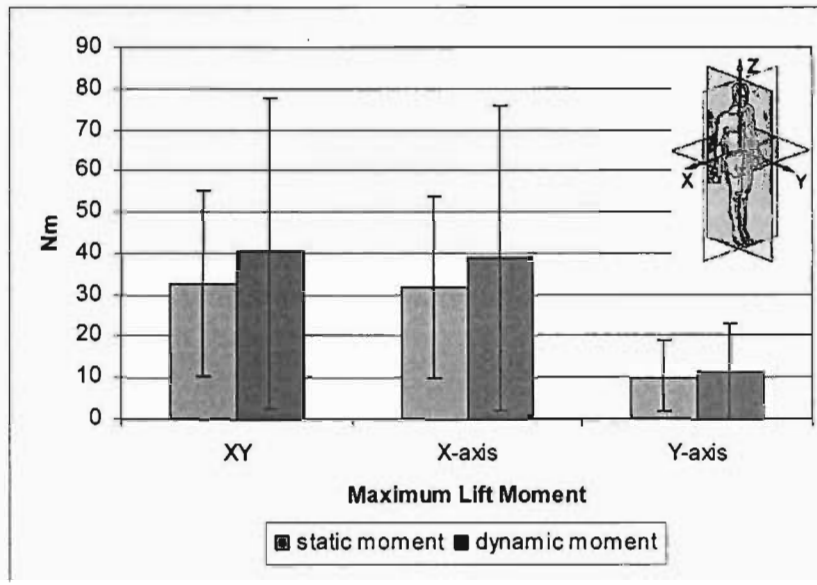


Figure 3-11. Comparison between the static and dynamic moment variables.

Table 3-6. List of the full and abbreviated names of all the variables in the load moment exposure database.

	Variable Full Name	Units	Abbreviated Name
1	Duration	seconds	duration
2	Duration of non-load exposure	seconds	durationne
3	Maximum XY Moment Arm	m	maxxyma
4	Percent Time of Maximum XY Moment Arm	%	ptmaxxyma
5	Start XY Moment Arm	m	sxyma
6	End XY Moment Arm	m	exyma
7	Maximum Resultant Moment Arm	m	mresma
8	Percent Time of Maximum Resultant Moment Arm	%	ptmresma
9	Start Box Height	m	sboxh
10	End Box Height	m	eboxh
11	Start Asymmetry	Degrees	sasym
12	End Asymmetry	Degrees	easym
13	Box Weight	N	asmass
14	Maximum Dynamic Z Force	N	maxdz
15	Percent Time of Maximum Dynamic Z Force	%	ptmaxdz
16	Average Dynamic Z Force	N	avedz
17	Absolute Maximum Dynamic Y Force	N	amaxdy
18	Percent Time of Absolute Maximum Dynamic Y Force	%	ptamaxdy
19	Absolute Maximum Dynamic YZ Force	N	amaxdyz
20	Percent Time of Absolute Maximum Dynamic YZ Force	%	ptamaxdyz
21	Absolute Maximum XY*Lift Static Moment	N*m	amxylsm
22	Percent Time of Absolute Maximum XY*Lift Static Moment	%	ptamxylsm
23	Box Asymmetry at Absolute Maximum XY*Lift Static Moment	Degrees	baamxylsm
24	Box Rightward X Acceleration at Absolute Maximum XY*Lift Static Moment	m/Second^2	braamxylsm
25	Box Leftward X Acceleration at Absolute Maximum XY*Lift Static Moment	m/Second^2	blaamxylsm
26	Box Forward Y Acceleration at Absolute Maximum XY*Lift Static Moment	m/Second^2	bfaamxylsm
27	Box Backward Y Acceleration at Absolute Maximum XY*Lift Static Moment	m/Second^2	bbaamxylsm
28	Box Up Z Acceleration at Absolute Maximum XY*Lift Static Moment	m/Second^2	buaamxylsm
29	Box Down Z Acceleration at Absolute Maximum XY*Lift Static Moment	m/Second^2	bdaamxylsm
30	Sagittal Trunk Angle at Absolute Maximum XY*Lift Static Moment	Degrees	staamxylsm
31	Absolute Average XY*Lift Static Moment	N*m	aaxysm

32	Absolute Maximum X-axis Static Lift Moment	N*m	amxsm
33	Percent Time of Absolute Maximum X-axis Static Lift Moment	%	ptamxslm
34	Box Asymmetry at Absolute Maximum X-axis Static Lift Moment	Degrees	baamxslm
35	Box Rightward X Acceleration at Absolute Maximum X-axis Static Moment	m/Second^2	braamxslm
36	Box Leftward X Acceleration at Absolute Maximum X-axis Static Moment	m/Second^2	blaamxslm
37	Box Forward Y Acceleration at Absolute Maximum X-axis Static Moment	m/Second^2	bfaamxslm
38	Box Backward Y Acceleration at Absolute Maximum X-axis Static Moment	m/Second^2	bbaamxslm
39	Box Up Z Acceleration at Absolute Maximum X-axis Static Moment	m/Second^2	buaamxslm
40	Box Down Z Acceleration at Absolute Maximum X-axis Static Moment	m/Second^2	bdaamxslm
41	Sagittal Trunk Angle at Absolute Maximum X-axis Static Lift Moment	Degrees	staamxslm
42	Absolute Maximum Y-axis Static Lift Moment	N*m	amyslm
43	Percent Time of Absolute Maximum Y-axis Static Lift Moment	%	ptamyslm
44	Box Asymmetry at Absolute Maximum Y-axis Static Lift Moment	Degrees	baamyslm
45	Box Rightward X Acceleration at Absolute Maximum Y-axis Static Moment	m/Second^2	braamyslm
46	Box Leftward X Acceleration at Absolute Maximum Y-axis Static Moment	m/Second^2	blaamyslm
47	Box Forward Y Acceleration at Absolute Maximum Y-axis Static Moment	m/Second^2	bfaamyslm
48	Box Backward Y Acceleration at Absolute Maximum Y-axis Static Moment	m/Second^2	bbaamyslm
49	Box Up Z Acceleration at Absolute Maximum Y-axis Static Moment	m/Second^2	buaamyslm
50	Box Down Z Acceleration at Absolute Maximum Y-axis Static Moment	m/Second^2	bdaamyslm
51	Sagittal Trunk Angle at Absolute Maximum Y-axis Static Lift Moment	Degrees	staamyslm
52	Absolute Maximum X-axis Dynamic Lift Moment	N*m	amxdlm
53	Percent Time of Absolute Maximum X-axis Dynamic Lift Moment	%	ptamxdlm
54	Box Asymmetry at Absolute Maximum X-axis Dynamic Lift Moment	Degrees	baamxdlm
55	Box Rightward X Acceleration at Absolute Maximum X-axis Dynamic Moment	m/Second^2	braamxdlm
56	Box Leftward X Acceleration at Absolute Maximum X-axis Dynamic Moment	m/Second^2	blaamxdlm
57	Box Forward Y Acceleration at Absolute Maximum X-axis Dynamic Moment	m/Second^2	bfaamxdlm
58	Box Backward Y Acceleration at Absolute Maximum X-axis Dynamic Moment	m/Second^2	bbaamxdlm
59	Box Up Z Acceleration at Absolute Maximum X-axis Dynamic Moment	m/Second^2	buaamxdlm
60	Box Down Z Acceleration at Absolute Maximum X-axis Dynamic Moment	m/Second^2	bdaamxdlm
61	Sagittal Trunk Angle at Absolute Maximum X-axis Dynamic Lift Moment	Degrees	staamxdlm
62	Absolute Maximum Y-axis Dynamic Lift Moment	N*m	amydlm
63	Percent Time of Absolute Maximum Y-axis Dynamic Lift Moment	%	ptamydlm
64	Box Asymmetry at Absolute Maximum Y-axis Dynamic Lift Moment	Degrees	baamydlm

65	Box Rightward X Acceleration at Absolute Maximum Y-axis Dynamic Moment	m/Second^2	braamydlm
66	Box Leftward X Acceleration at Absolute Maximum Y-axis Dynamic Moment	m/Second^2	blaamydlm
67	Box Forward Y Acceleration at Absolute Maximum Y-axis Dynamic Moment	m/Second^2	bfaamydlm
68	Box Backward Y Acceleration at Absolute Maximum Y-axis Dynamic Moment	m/Second^2	bbaamydlm
69	Box Up Z Acceleration at Absolute Maximum Y-axis Dynamic Moment	m/Second^2	buaamydlm
70	Box Down Z Acceleration at Absolute Maximum Y-axis Dynamic Moment	m/Second^2	bdaamydlm
71	Sagittal Trunk Angle at Absolute Maximum Y-axis Dynamic Lift Moment	Degrees	staamydlm
72	Absolute Maximum XY*Lift Dynamic Moment	N*m	amxyldm
73	Percent Time of Absolute Maximum XY*Lift Dynamic Moment	%	ptamxyldm
74	Box Asymmetry at Absolute Maximum XY*Lift Dynamic Moment	Degrees	baamxyldm
75	Box Rightward X Acceleration at Absolute Maximum XY*Lift Dynamic Moment	m/Second^2	braamxyldm
76	Box Leftward X Acceleration at Absolute Maximum XY*Lift Dynamic Moment	m/Second^2	blaamxyldm
77	Box Forward Y Acceleration at Absolute Maximum XY*Lift Dynamic Moment	m/Second^2	bfaamxyldm
78	Box Backward Y Acceleration at Absolute Maximum XY*Lift Dynamic Moment	m/Second^2	bbaamxyldm
79	Box Up Z Acceleration at Absolute Maximum XY*Lift Dynamic Moment	m/Second^2	buaamxyldm
80	Box Down Z Acceleration at Absolute Maximum XY*Lift Dynamic Moment	m/Second^2	bdaamxyldm
81	Sagittal Trunk Angle at Absolute Maximum XY*Lift Dynamic Moment	Degrees	staamxyldm
82	Absolute Average XY*Lift Dynamic Lift Moment	N*m	aaxyldm
83	Absolute Maximum Total Dynamic Sagittal Moment	N*m	amyzdbm
84	Percent Time of Absolute Maximum Total Dynamic Sagittal Moment	%	ptamyzdbm
85	Box Asymmetry at Absolute Maximum Total Dynamic Sagittal Moment	Degrees	baamyzdbm
86	Box Rightward X Acceleration at Absolute Maximum Total Dynamic Sagittal Moment	m/Second^2	braamyzdbm
87	Box Leftward X Acceleration at Absolute Maximum Total Dynamic Sagittal Moment	m/Second^2	blaamyzdbm
88	Box Forward Y Acceleration at Absolute Maximum Total Dynamic Sagittal Moment	m/Second^2	bfaamyzdbm
89	Box Backward Y Acceleration at Absolute Maximum Total Dynamic Sagittal Moment	m/Second^2	bbaamyzdbm
90	Box Up Z Acceleration at Absolute Maximum Total Dynamic Sagittal Moment	m/Second^2	buaamyzdbm
91	Box Down Z Acceleration at Absolute Maximum Total Dynamic Sagittal Moment	m/Second^2	bdaamyzdbm
92	Sagittal Trunk Angle at Absolute Maximum Total Dynamic Sagittal Moment	Degrees	staamyzdbm
93	Absolute Maximum Resultant Dynamic Moment	N*m	amrdbm
94	Percent Time of Absolute Maximum Resultant Dynamic Moment	%	ptamrdbm
95	Box Asymmetry at Absolute Maximum Resultant Dynamic Moment	Degrees	baamrdbm
96	Box Rightward X Acceleration at Absolute Maximum Resultant Dynamic Moment	m/Second^2	braamrdbm
97	Box Leftward X Acceleration at Absolute Maximum Resultant Dynamic Moment	m/Second^2	blaamrdbm

98	Box Forward Y Acceleration at Absolute Maximum Resultant Dynamic Moment	m/Second^2	bfaamrdbm
99	Box Backward Y Acceleration at Absolute Maximum Resultant Dynamic Moment	m/Second^2	bbaamrdbm
100	Box Up Z Acceleration at Absolute Maximum Resultant Dynamic Moment	m/Second^2	buaamrdbm
101	Box Down Z Acceleration at Absolute Maximum Resultant Dynamic Moment	m/Second^2	bdaamrdbm
102	Sagittal Trunk Angle at Absolute Maximum Resultant Dynamic Moment	Degrees	staamrdbm
103	Absolute Average Resultant Dynamic Moment	N*m	aardbm
104	Integrated Absolute Box Weight	N	ismass
105	Integrated Dynamic Z Force	N	idfrz
106	Integrated Absolute Dynamic Y Force	N	iadfry
107	Integrated Absolute Dynamic YZ Force	N	iadyzf
108	Integrated Absolute X-axis Static Lift Moment	N*m	iaxslm
109	Integrated Absolute Y-axis Static Lift Moment	N*m	iayslm
110	Integrated Absolute XY*Lift Static Moment	N*m	iaxylsm
111	Integrated Absolute X-axis Dynamic Moment	N*m	iaxdm
112	Integrated Absolute Y-axis Dynamic Moment	N*m	iaydm
113	Integrated Absolute XY*Lift Dynamic Moment	N*m	iaxyldm
114	Integrated Total Dynamic Sagittal Moment	N*m	iyzdbm
115	Integrated Resultant Dynamic Moment	N*m	irdbm
116	Integrated Sagittal Trunk Angle	Degrees	isagp
117	Integrated Flexion Sagittal Velocity	Degrees/Second	isagfv
118	Integrated Extension Sagittal Velocity	Degrees/Second	isagev
119	Integrated Sagittal Acceleration	Degrees/Second^2	isagacc
120	Integrated Sagittal Deceleration	Degrees/Second^2	isagdec
121	Integrated Rightwards Lateral Trunk Angle	Degrees	ilatrp
122	Integrated Leftwards Lateral Trunk Angle	Degrees	ilatlp
123	Integrated Rightwards Lateral Velocity	Degrees/Second	ilatrv
124	Integrated Leftwards Lateral Velocity	Degrees/Second	ilatlv
125	Integrated Lateral Acceleration	Degrees/Second^2	ilatacc
126	Integrated Lateral Deceleration	Degrees/Second^2	ilatdec
127	Integrated Box Rightwards X Velocity	m/Second	ibxrvel
128	Integrated Box Leftwards X Velocity	m/Second	ibxlvel
129	Integrated Box Forwards Y Velocity	m/Second	ibfyvel
130	Integrated Box Backwards Y Velocity	m/Second	ibbyvel

131	Integrated Box Up Z Velocity	m/Second	ibuzacc
132	Integrated Box Down Z Velocity	m/Second	ibdzacc
133	Integrated Box Resultant Velocity	m/Second	ibrvel
134	Integrated Box X Acceleration	m/Second^2	ibxacc
135	Integrated Box X Deceleration	m/Second^2	ibxdec
136	Integrated Box Y Acceleration	m/Second^2	ibyacc
137	Integrated Box Y Deceleration	m/Second^2	ibydec
138	Integrated Box Z Acceleration	m/Second^2	ibzacc
139	Integrated Box Z Deceleration	m/Second^2	ibzdec
140	Integrated Box Resultant Acceleration Without Gravity	m/Second^2	ibraccng
141	Peak*Duration Absolute Box Weight	N	pdasm
142	Peak*Duration Absolute Dynamic Z Force	N	pdadzf
143	Peak*Duration Absolute Dynamic Y Force	N	pdadyf
144	Peak*Duration Absolute Dynamic YZ Force	N	pdadyzf
145	Peak*Duration Absolute X-axis Static Lift Moment	N*m	pdaxslm
146	Peak*Duration Absolute Y-axis Static Lift Moment	N*m	pdayslm
147	Peak*Duration Absolute XY*Lift Static Moment	N*m	pdaxyslm
148	Peak*Duration Absolute X-axis Dynamic Moment	N*m	pdaxdm
149	Peak*Duration Absolute Y-axis Dynamic Moment	N*m	pdaydm
150	Peak*Duration Absolute XY*Lift Dynamic Moment	N*m	pdaxldm
151	Peak*Duration Total Dynamic Sagittal Moment	N*m	pdyzdbm
152	Peak*Duration Resultant Dynamic Moment	N*m	pdrdbm
153	Peak*Duration Sagittal Trunk Angle	Degrees	pdsagp
154	Peak*Duration Sagittal Velocity	Degrees/Second	pdsagv
155	Peak*Duration Sagittal Acceleration	Degrees/Second^2	pdsaga
156	Peak*Duration Lateral Trunk Angle	Degrees	pdlatp
157	Peak*Duration Lateral Velocity	Degrees/Second	pdlatv
158	Peak*Duration Lateral Acceleration	Degrees/Second^2	pdlata
159	Peak*Duration Box X Velocity	m/Second	pdbxvel
160	Peak*Duration Box Y Velocity	m/Second	pdbyvel
161	Peak*Duration Box Z Velocity	m/Second	pdbzvel
162	Peak*Duration Box Resultant Velocity	m/Second	pdbrvel
163	Peak*Duration Box X Acceleration	m/Second^2	pdbxacc

164	Peak*Duration Box Y Acceleration	m/Second^2	pdbyacc
165	Peak*Duration Box Z Acceleration	m/Second^2	pdbzacc
166	Peak*Duration Box Resultant Acceleration Without Gravity	m/Second^2	pdbaccng
167	Absolute Maximum Sagittal Trunk Angle	Degrees	amsagp
168	Percent Time of Absolute Maximum Sagittal Trunk Angle	%	ptamsagp
169	Absolute XY*Lift Static Moment at Absolute Maximum Sagittal Trunk Angle	N*m	amxysmamp
170	Absolute X-axis Static Lift Moment at Absolute Maximum Sagittal Trunk Angle	N*m	amxslmamp
171	Absolute Y-axis Static Lift Moment at Absolute Maximum Sagittal Trunk Angle	N*m	amyslmamp
172	Absolute X-axis Dynamic Lift Moment at Absolute Maximum Sagittal Trunk Angle	N*m	amxdlmamp
173	Absolute Y-axis Dynamic Lift Moment at Absolute Maximum Sagittal Trunk Angle	N*m	amydlmamp
174	Absolute Total Dynamic Sagittal Moment at Absolute Maximum Sagittal Trunk Angle	N*m	amyzdbmamp
175	Absolute Resultant Moment at Absolute Maximum Sagittal Trunk Angle	N*m	amrmamp
176	Maximum Right Lateral Trunk Angle	Degrees	mrlatp
177	Percent Time of Maximum Right Lateral Trunk Angle	%	ptmrlatp
178	Maximum Left Lateral Trunk Angle	Degrees	mllatp
179	Percent Time of Maximum Left Lateral Trunk Angle	%	ptmlatp
180	Maximum Flexion Sagittal Trunk Velocity	Degrees/Second	msagfv
181	Percent Time of Maximum Flexion Sagittal Trunk Velocity	%	ptmsagfv
182	Maximum Extension Sagittal Trunk Velocity	Degrees/Second	msagev
183	Percent Time of Maximum Extension Sagittal Trunk Velocity	%	ptmsagev
184	Maximum Sagittal Trunk Acceleration	Degrees/Second^2	msagacc
185	Percent Time of Maximum Sagittal Trunk Acceleration	%	ptmsagacc
186	Maximum Sagittal Trunk Deceleration	Degrees/Second^2	msagdec
187	Percent Time of Maximum Sagittal Trunk Deceleration	%	ptmsagdec
188	Maximum Rightwards Lateral Trunk Velocity	Degrees/Second	mrlatv
189	Percent Time of Maximum Rightwards Lateral Trunk Velocity	%	ptmrlatv
190	Maximum Leftwards Lateral Trunk Velocity	Degrees/Second	mllatv
191	Percent Time of Maximum Leftwards Lateral Trunk Velocity	%	ptmlatv
192	Maximum Lateral Trunk Acceleration	Degrees/Second^2	mlatacc
193	Percent Time of Maximum Lateral Trunk Acceleration	%	ptmlatacc
194	Maximum Lateral Trunk Deceleration	Degrees/Second^2	mlatdec
195	Percent Time of Maximum Lateral Trunk Deceleration	%	ptmlatdec
196	Maximum Box Rightwards X Velocity	m/Second	mbxrtvel

197	Percent Time of Maximum Box Rightwards X Velocity	%	ptmbxrtv
198	Maximum Box Leftwards X Velocity	m/Second	mbxleftv
199	Percent Time of Maximum Box Leftwards X Velocity	%	ptmbxleftv
200	Maximum Box Forwards Y Velocity	m/Second	mbxfvel
201	Percent Time of Maximum Box Forwards Y Velocity	%	ptmbxfvel
202	Maximum Box Backwards Y Velocity	m/Second	mbxbvel
203	Percent Time of Maximum Box Backwards Y Velocity	%	ptmbxbvel
204	Maximum Box Up Z Velocity	m/Second	mbxupv
205	Percent Time of Maximum Box Up Z Velocity	%	ptmbxupv
206	Maximum Box Down Z Velocity	m/Second	mbxdwnv
207	Percent Time of Maximum Box Down Z Velocity	%	ptbxdwnv
208	Absolute Maximum Box Resultant Velocity	m/Second	ambrvel
209	Percent Time of Absolute Maximum Box Resultant Velocity	%	ptambrvel
210	Maximum Box X Acceleration	m/Second^2	mbxacc
211	Percent Time of Maximum Box X Acceleration	%	ptmbxacc
212	Maximum Box X Deceleration	m/Second^2	mbxdec
213	Percent Time of Maximum Box X Deceleration	%	ptmbxdec
214	Maximum Box Y Acceleration	m/Second^2	mbyacc
215	Percent Time of Maximum Box Y Acceleration	%	ptmbyacc
216	Maximum Box Y Deceleration	m/Second^2	mbydec
217	Percent Time of Maximum Box Y Deceleration	%	ptmbydec
218	Maximum Box Z Acceleration	m/Second^2	mbzacc
219	Percent Time of Maximum Box Z Acceleration	%	ptmbzacc
220	Maximum Box Z Deceleration	m/Second^2	mbzdec
221	Percent Time of Maximum Box Z Deceleration	%	ptmbzdec
222	Absolute Maximum Box Resultant Acceleration Without Gravity	m/Second^2	ambraccng
223	Percent Time of Absolute Maximum Box Resultant Acceleration Without Gravity	%	ptambraccng
224	1993 NIOSH Recommended Weight Limit (RWL)	KG	RWL
225	1993 NIOSH Lifting Index (LI)	N/A	LI
226	Box Forwards Y Velocity at Destination	m/Second	bfiyvel
227	Frequency	Lifts/minute	freq

3) Trunk kinematics

Trunk kinematic variables include maximum sagittal and lateral trunk (leftwards and rightwards) angles, maximum sagittal (flexion and extension) and lateral (leftwards and rightwards) velocity, and maximum sagittal (flexion and extension) and lateral (leftwards and rightwards) acceleration.

The maximum sagittal trunk angle averaged 50.3 degrees. The mean of the lateral trunk angle for leftward and rightward bending were 12.9 and 14.4 degrees, respectively. Figure 3-12 shows the mean of the maximum trunk velocity in different directions. Extension and lateral bending had a slightly higher velocity (above 80 deg/s) than the flexion velocity (69 deg/s). Figure 3-13 shows the maximum trunk acceleration in different directions. It can be seen that the lateral accelerations were higher than the sagittal plane accelerations (about a 25% increase).

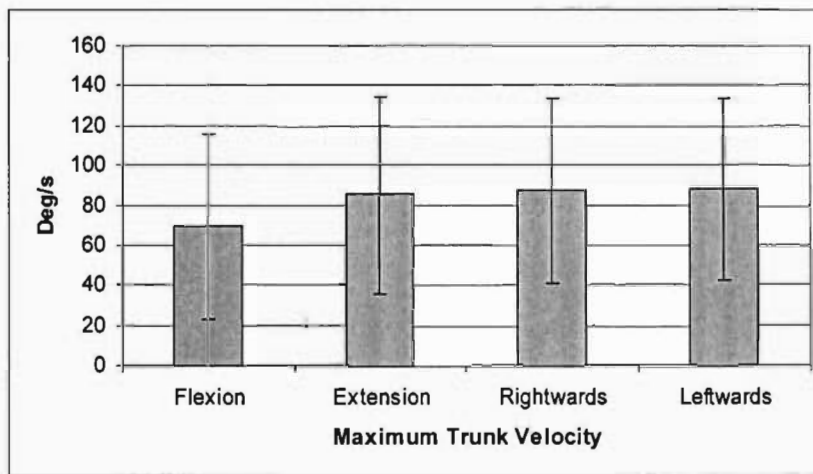


Figure 3-12. Maximum trunk velocity in different directions.

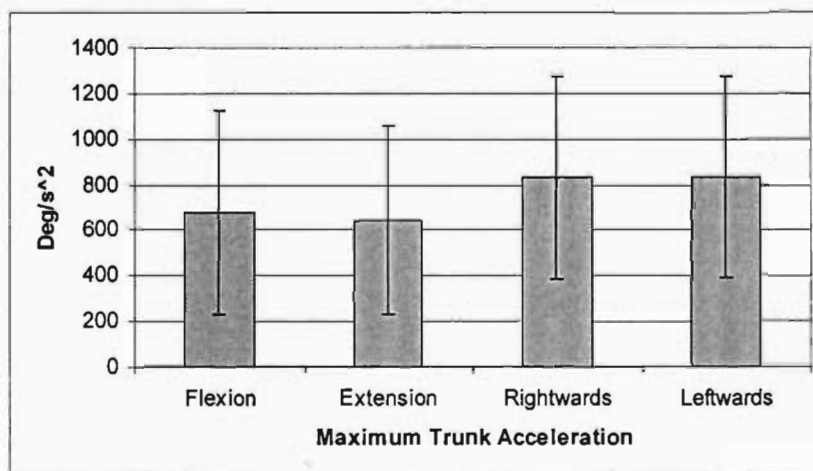


Figure 3-13. Maximum trunk acceleration in different directions.

4) Box kinematics

Box kinematics variables describe how the box moves within the space. They include maximum box velocity and acceleration in the X (rightwards and leftwards), Y (forwards and backwards), and Z (up and down) directions, as well as the resultant velocity and acceleration.

Figure 3-14 shows the mean of the maximum box velocity in six different directions. The velocity going upwards was the highest among all the directions, indicating the box was quickly lifted up. The forward velocity was the second highest. High forward velocity could happen when the box was pushed forward or tossed to the destination. This variable corresponds to the high value of another variable – Box Forward Y Velocity at Destination (bfyveldes).

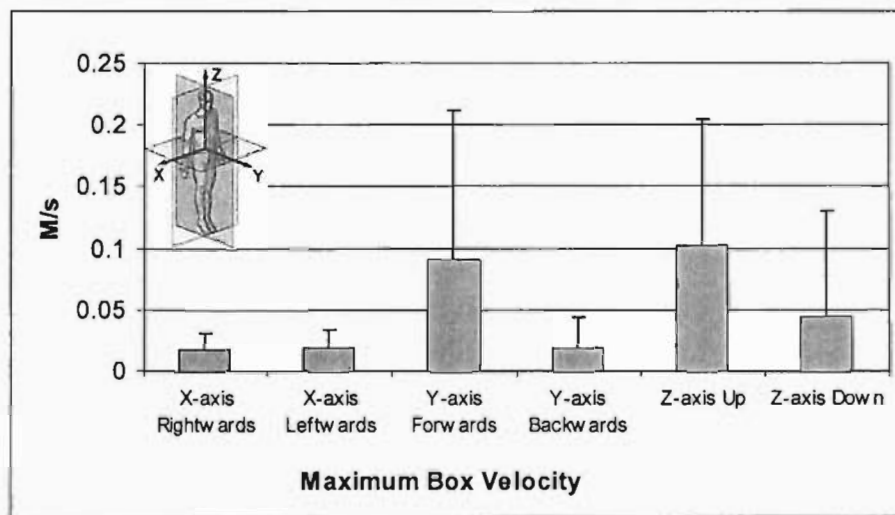


Figure 3-14. Maximum box velocity in different directions.

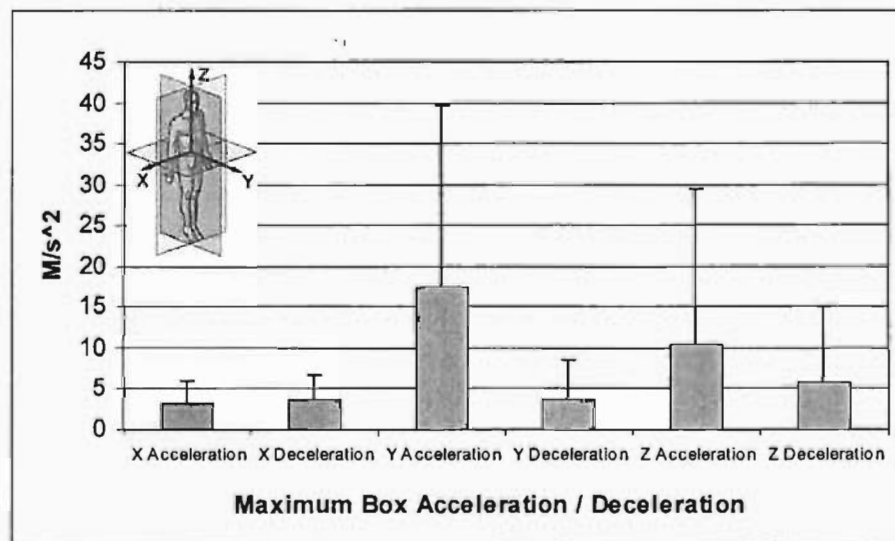


Figure 3-15. Maximum box acceleration/deceleration in different directions.

Figure 3-15 plots the mean of the maximum box acceleration/deceleration. It can be seen that the Y and Z accelerations were among the highest ones across all directions. These results correspond to the velocity profile of the box.

To further describe the characteristics of box movement, box acceleration/deceleration at the maximum static or dynamic moment was also calculated. These variables include box X, Y, and Z acceleration/deceleration at the maximum X-axis, Y-axis, and XY static moment, the maximum X-axis, Y-axis, and XY dynamic moment, and the maximum total sagittal and resultant dynamic moment. An exemplary plot of the acceleration profile at the maximum resultant dynamic moment is shown in Figure 3-16. The plot has the same trend as the maximum box acceleration and deceleration, with the Y acceleration being the highest across all directions. The data of box acceleration/deceleration at other maximum moments have similar trends.

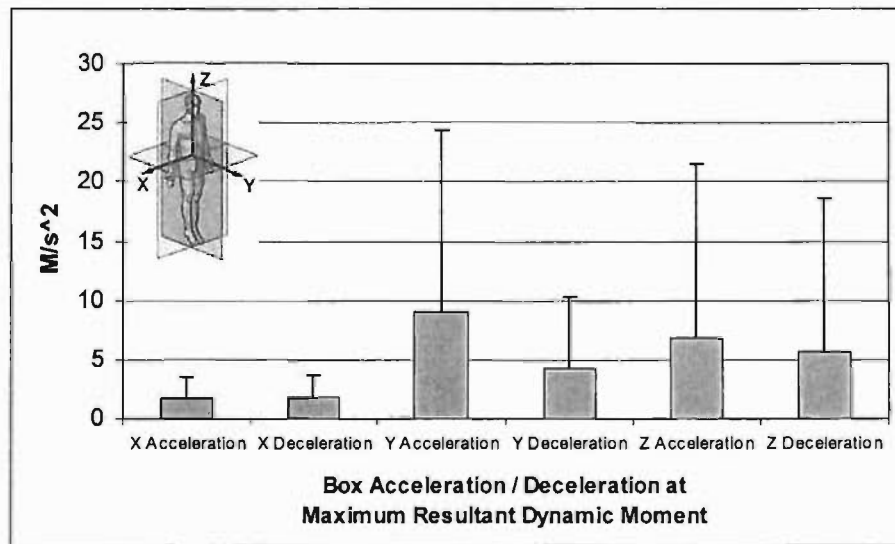


Figure 3-16. Box acceleration/deceleration at maximum resultant dynamic moment.

5) Timing variables

Timing variables describe when a certain biomechanical measure occurs during a lift cycle. They are expressed as the percentage of the total time of a lift. For example, the variable “Percent Time of Max XY Moment Arm” is the time from the beginning of a lift to the point when the maximum XY moment arm occurs divided by the total duration of the lift. From the distribution plot of this variable (see Appendix A-2), it can be seen that it is not normally distributed. Most of the maximum XY moment arms occurred either at the beginning or the end of the lift, when the subject picked up the box or put it down.

There are 39 timing variables in the database. Biomechanical measures that are described by these variables include maximum moment arms, box weight, dynamic forces, moments, trunk angles, trunk velocities, trunk accelerations/decelerations, box velocities, box accelerations/decelerations.

The distribution plots show that most of the peaks of the moment arms, dynamic forces, moments, trunk angles, and box kinematics happened either at the start or the end of the lift, making the curves of the plots “U-shaped”. But for the trunk velocity and acceleration variables, the distribution plots were more like “W-shaped” curves. This indicated that there were significant amount of trunk movement during the course of the manual materials handling exertions.

6) Cumulative variables

To investigate the cumulative effect of the job, cumulative variables were calculated for box weight, dynamic forces, static and dynamics moments, trunk kinematics, and box kinematics variables. Two methods were used to calculate the cumulative variables. The first method was summing the values at each data point over an entire lifting cycle. The time interval between data points was 0.025s. This method calculates the total area underneath a curve. These variables are called “Integrated + variable name”. The second method used the peak value of a biomechanical measure during an exertion cycle multiplied by the duration of the exertion. These variables are called “Peak* duration + variable name”.

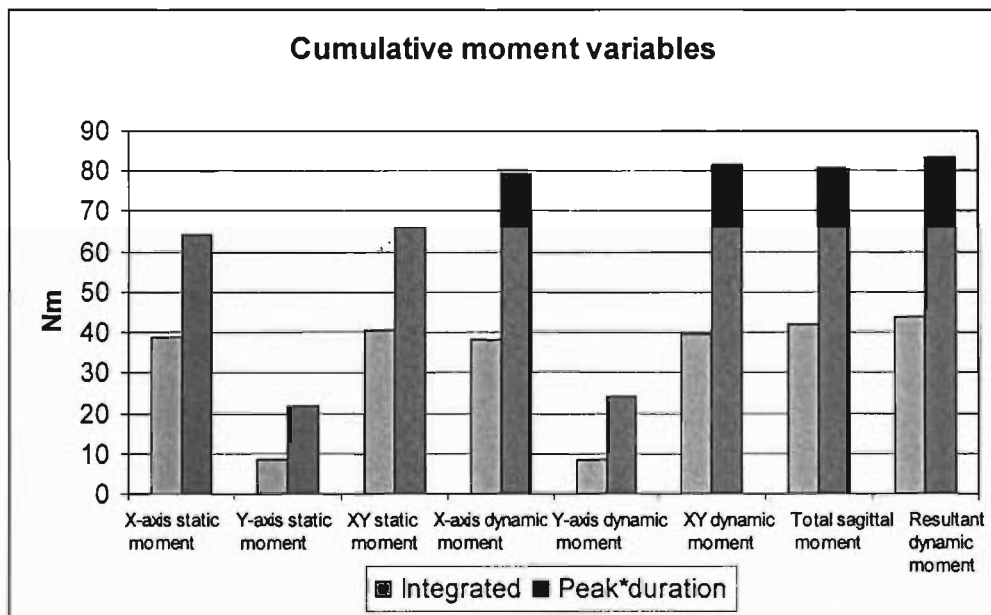


Figure 3-17. An example of the differences between the two methods of calculating the cumulative variables.

Because of the difference in the calculation methods, the “Peak*duration” variables were always larger than the “Integrated” variables. Figure 3-17 shows an example of the enlargement for the cumulative moment variables. The values of the “Integrated” moment variables were 39-66% less than the variables calculated with the “Peak*duration” method.

3.3.2 Incidence rates

The incidence rates (I200k) of back injuries for 50 jobs are shown in Figure 3-18. The minimum injury rate was 0, while the maximum was 100. The mean injury rate is 14.0 with a standard deviation of 22.5.

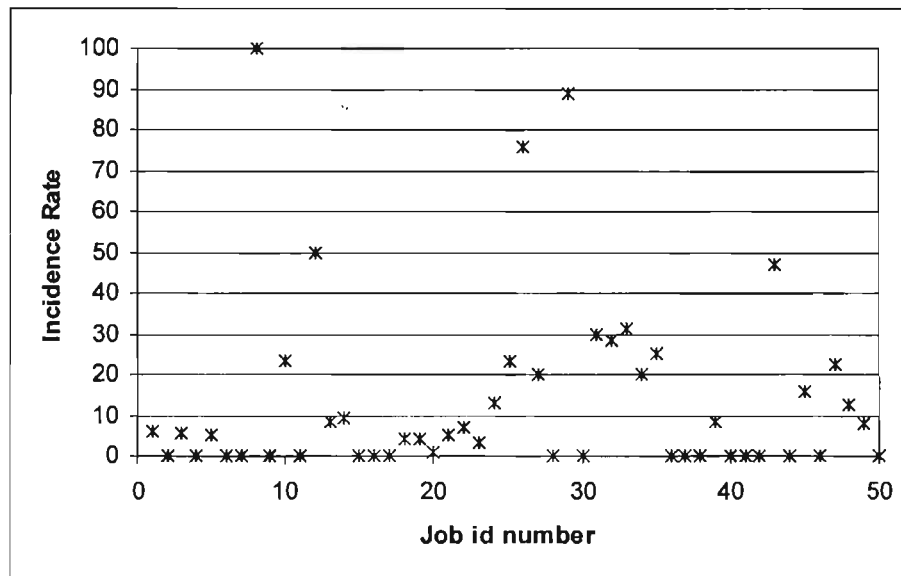


Figure 3-18. Incidence rates (I200k) of back injuries for 50 jobs monitored.

3.3.3 Low back functional impairment test and symptom survey

888 subjects participated in the baseline symptom and psychosocial survey. The age of the participants ranged from 18 to 68 years, with an average age of 33.9 years. The average weight of the subjects was 187.6 (43.1) lbs. The average height of the baseline sample was 69.5 (3.67) inches. Table 3-7 shows the results of the baseline low back functional impairment test and symptom and psychosocial survey.

There were 11 questions about the psychosocial aspects of the job. They were grouped into four categories: job control, supervisor support, coworker support, and job satisfaction. The five options for the four job control questions were given scores from 1 to 5, with 1 being “Very little” and 5 “Very much”. The mean of the four questions was calculated for each subject. The overall mean score of job control for all subjects was 2.84, which was close to “Moderate” amounts.

Each of the three questions on supervisor (boss) support has four options. 0 score was given to “Not at all” and 3 was given to “Very much”. The mean score of supervisor support was 1.65, which was between “A little” and “Much” support. There are also three questions on co-worker support. The scoring system was the same as the supervisor support questions. The mean score of co-worker support was 1.77 for all subjects. There is one question about job satisfaction, with 0 score being “Not at all satisfied” and 3

being “very satisfied”. The mean score was 2.09 for all subjects, which corresponded to “somewhat satisfied”.

The rest of the survey was related to individual factors and symptoms. The results showed that 53% of subjects have smoked at least 100 cigarettes in their entire life. The mean time the subjects have worked for their current company was between 1 and 5 years. The mean time the subjects have worked in their current job was about 1 to 3 years. The mean time the subjects have been doing same kind of manual material handling work was 3 to 5 years. The average number of hours they work per week was about 40 hours.

Nearly half (46%) of the subjects have had back pain that has limited their activities. At baseline 29% of the subjects have had back pain more than once in the last 12 months that has limited their activities. Thirty-three percent of the subjects have ever had low back pain every day for a week or more. 21% of the subjects also reported to have back pain everyday for a week or more in the past 12 months. The average number of times (in the past 12 months) the subjects have visited a doctor or other health care provider for their back symptoms was 0.48 times. The average number of days they have missed work because of back symptoms (in the past 12 months) was 0.23 days. Only 5% of the subjects said their back pain in the past 12 months resulted from an accident such as slipping or falling.

21% of the subjects also had knee pain in the past 12 months that restricted their activities. Only 6% of them said their knee pain resulted from a slipping or falling accident. About 17% of them had knee pain more than once. About the same number of subjects (20%) had shoulder pain in the past year that restricted their activities. 17% of the subjects had shoulder pain more than once. The overall rating of the physical effort level demanded by their job was 5.94 on a Borg scale, which was between “Strong” and “Very strong”.

Follow-up data was collected on 529 workers however 78 workers had changed jobs during the study so there data was not evaluated. The average follow-up rate for all facilities was 60%. 451 subjects stayed on the same job and filled out the survey. Table 3-8 shows the results of the follow-up symptom survey.

The probability of normal (Pn) from the low back functional test ranged from 0.01 to 0.98 at baseline, with a mean score of 0.56 (0.26). At follow-up, the mean score of all the subjects averaged 0.52 (0.27).

Table 3-7. Results of the baseline low back functional impairment test and symptom and psychosocial survey.

Variable	Questions from the survey	Mean	Std
Ageb	Age	33.91	10.67
Wtb	Weight (lb)	187.60	43.13
Htb	Height (in)	69.52	3.67
Bcontrol	Job control (Question 20)	2.84	1.04
Bsboss	Supervisor support (Question 21)	1.65	0.74
Bscow	Coworker support (Question 21)	1.77	0.67
Bsatis	Job satisfaction (Question 22)	2.09	0.76
Pn1	Probability of Normal (Low Back Functional Test)	0.56	0.26
BQ3	Have you smoked at least 100 cigarettes in your life?	0.53	0.50
BQ4	How long have you worked at the company?	2.53	1.50
BQ5	How long have you worked in your current job?	2.23	1.42
BQ6	How long have you been doing this kind of work?	3.09	1.52
BQ7	Number of hours per week worked	1.19	0.66
BQ8	Have you ever had back pain that has limited your activities?	0.46	0.50
BQ9	Have you had back pain more than once in the last 12 months that has limited your activities?	0.29	0.45
BQ10	Have you ever had low back pain every day for a week (7 days) or more?	0.33	0.47
BQ11	In the past 12 months, have you had back pain every day for a week (7 days) or more?	0.21	0.41
BQ12	In the past 12 months, how many times have you seen a doctor or other health care provider for your back symptoms?	0.48	0.92
BQ13	How many days have you missed work in the past 12 months because of back symptoms?	0.23	0.62
BQ14	Did the back pain you had in the past 12 months result from an accident such as slipping or falling?	0.05	0.22
BQ15	Have you experienced knee pain in the past 12 months that restricted your activities?	0.21	0.41
BQ16	Did the knee pain you had in the past 12 months result from an accident such as slipping or falling?	0.06	0.23
BQ17	Have you experienced knee pain more than once in the past 12 months that restricted your activities?	0.17	0.38
BQ18	In the past 12 months have you experienced shoulder pain that restricts your activities?	0.20	0.40
BQ19	Have you experienced shoulder pain that restricts your activities more than once in the past 12 months?	0.17	0.37
BQ23	Overall physical effort level demanded by the job	5.94	2.46

Table 3-8. Results of the follow-up low back functional impairment test and symptom and psychosocial survey.

Variable	Questions from the survey	Mean	Std
Fcontrol	Job control	2.86	0.96
Fsboss	Supervisor support	1.73	0.74
Fscow	Coworker support	1.73	0.62
Fsatis	Job satisfaction	2.17	0.69
Pnf	Probability of Normal (Low Back Functional Test)	0.52	0.27
FQ8	Have you ever had back pain that has limited your activities?	0.43	0.50
FQ9	Have you had back pain more than once in the last 12 months that has limited your activities?	0.26	0.44
FQ10	Have you ever had low back pain every day for a week (7 days) or more?	0.27	0.45
FQ11	In the past 12 months, have you had back pain every day for a week (7 days) or more?	0.19	0.39
FQ12	In the past 12 months, how many times have you seen a doctor or other health care provider for your back symptoms?	0.42	0.86
FQ13	How many days have you missed work in the past 12 months because of back symptoms?	0.17	0.48
FQ14	Did the back pain you had in the past 12 months result from an accident such as slipping or falling?	0.05	0.21
FQ15	Have you experienced knee pain in the past 12 months that restricted your activities?	0.16	0.37
FQ16	Did the knee pain you had in the past 12 months result from an accident such as slipping or falling?	0.05	0.22
FQ17	Have you experienced knee pain more than once in the past 12 months that restricted your activities?	0.11	0.32
FQ18	In the past 12 months have you experienced shoulder pain that restricts your activities?	0.15	0.36
FQ19	Have you experienced shoulder pain that restricts your activities more than once in the past 12 months?	0.13	0.34
FQ23	Overall physical effort level demanded by the job	5.95	2.43

Note : Follow-up data is on workers that stayed on the same job.

3.3.4 Statistical model

3.3.4.1 Statistical model for Prospective Change in Pn

To build the statistical model for Pn, a working database that contained the load moment exposure variables and the psychosocial and symptoms survey variables was set up. Because job was considered the unit of analysis, the mean of each variable by job was used as the predictor for the model. The names of most of the variables are simply “jm + variable name”, which indicates the “job mean” of the variable. For the cumulative variables, “jsf” was added to the each name, which indicates that the variable was summed up for all the exertions a worker did during the data collection period and a scaling factor was applied to scale it up to a 7-hour working day (8 hours minus 1 hour of breaks and lunch time). The mean of the variable for all the workers on that job was used as the predictor.

The outcome variable was the difference in Pn between the follow-up and baseline low back functional tests. A previous study (Marras, Parnianpour, Ferguson, Kim, Crowell, Bose, & Simon, 1995) showed that individual standard deviation in Pn between visits on different days was 0.07. Ninety-five percent of the variation between days would be explained with a change of 0.14. Therefore, a threshold for a significant change in Pn was defined as change of 0.14. If the difference between the follow-up and baseline Pn of an individual worker was less than -0.14, the worker was a case. This was because the follow-up Pn score decreased from the baseline score and the change was more than the 0.14 threshold. If the difference between the follow-up and baseline Pn was greater than 0, the worker was not a case. The workers with Pn change between 0 and -0.14 were not included in the analysis because the change could be due to normal variation of the test.

The definition of high risk and low risk jobs was based on the number of workers on the job at follow-up and the number of cases on the job. If the number of workers on the job is less than or equal to 2, the job was deleted because of the small sample size. If the number of workers on the job = 3, then at least 2 workers must be cases for the job to be high risk job. If the number of workers on the job = 4, then at least 2 must be cases for the job to be high risk job. If the number of workers on the job = 5, then at least 2 must be cases for the job to be a high risk job. If the number of workers on the job = 6 or more, then 30% of the workers must be cases for the job to be high risk. The jobs that do not meet the criteria were categorized as low risk jobs. Based on this definition 20 jobs were defined as high risk, 16 were identified as low risk jobs, and 14 jobs were excluded from the analysis based on sample size issues.

Table 3-9 lists the univariate logistic regression predicting the outcome of high risk of disability due to the job for Pn. The measures in the table are all continuous. The logistic regression models were weighted based on the number of workers on the job at follow-up. Several of the integrated factors have p-values and Wald Scores that are significant but the 95% confidence interval for the odds ratio is 1. This is due to the fact that measures themselves are very large resulting in very small estimates.

The multivariate model for predicting high risk of job disability defined by change in Pn required several steps due to the large number possible variables. First, CART software was used for variable selection. However, the 227 variables possible tend to be too many for even CART. Therefore, variables were grouped based on category of the variable. The groups included load moment (static, dynamic), torso position (including kinematics), box position, temporal variables, individual variables, and psychosocial variables. These categories represent our current understanding of risk factors (biomechanical, psychosocial, and individual) related to low back pain. The categories allow us to offer 20-40 variables to CART at one time. The top five variables from each category were offered again to CART to create a multi-category model. The cut-points from CART were used to dichotomized the continuous measures. The final logistic regression was selected based on biomechanical plausibility, statistical significance of each factor and overall model specificity and sensitivity. A correlation matrix of all the variables was also made to ensure that the variables selected were not highly correlated. The correlation matrix is included in Appendix A-3. One significant variable was selected each time from each of the categories.

Table 3-9. Univariate logistic regression for Pn.

Variable Name	Estimate	St Error	Wald Score	P-Values	Odds Ratio	95% Confidence Interval	
jmduration	1.9927	0.2618	57.9	0.0001	7.335	4.391	12.254
jmdurationne	0.03	0.0162	3.4	0.0635	1.03	0.998	1.064
jsfduration	-0.00018	0.000138	1.7	0.1877	1.000	1.000	1.000
jsfdurationne	-0.00028	0.000046	36.5	0.0001	1.000	1.000	1.000
jtduration	-0.00021	0.000038	29.7	0.0001	1.000	1.000	1.000
jmmaxyyma	18.0295	3.6494	24.4	0.0001	***	***	***
jmptmaxyyma	0.071	0.0239	8.9	0.0029	1.074	1.025	1.125
jmsxyyma	5.7302	3.7768	2.3	0.1292	***	***	***
jmexyyma	12.4283	4.1141	9.1	0.0025	***	***	***
jmmresma	15.0816	2.98	25.6	0.0001	***	***	***
jmptmresma	0.0526	0.0179	8.6	0.0034	1.054	1.018	1.092
jmsboxh	2.5844	1.3787	3.5	0.0609	***	***	***
jmeboxh	-4.0148	1.2012	11.2	0.0008	0.018	0.002	0.19
jmsasym	0.5372	0.0763	49.6	0.0001	1.711	1.474	1.987
jmeasym	0.7256	0.0884	67.3	0.0001	2.066	1.737	2.457
jmasmass	0.055	0.0126	19.1	0.0001	1.057	1.031	1.083
jmmaxdz	0.0263	0.00548	23.1	0.0001	1.027	1.016	1.038
jmptmaxdz	0.1852	0.0297	39.0	0.0001	1.204	1.136	1.276
jmavedz	0.00856	0.00883	0.9	0.332	1.009	0.991	1.026
jmamaxdy	0.0603	0.0101	35.4	0.0001	1.062	1.041	1.084
jmptamaxdy	0.0912	0.038	5.8	0.0164	1.096	1.017	1.18
jmamaxdyz	0.0329	0.00533	38.2	0.0001	1.033	1.023	1.044
jmptamaxdyz	0.2206	0.0331	44.4	0.0001	1.247	1.169	1.33
jmamxylsm	0.119	0.0183	42.4	0.0001	1.126	1.087	1.167
jmptamxylsm	0.2291	0.0347	43.6	0.0001	1.257	1.175	1.346
jmbaamxylsm	0.5476	0.0788	48.2	0.0001	1.729	1.482	2.018
jmbraamxylsm	1.2072	0.3734	10.5	0.0012	3.344	1.609	6.952
jmblaamxylsm	-1.138	0.4381	6.7	0.0094	0.32	0.136	0.756
jmbfaamxylsm	0.7842	0.1418	30.6	0.0001	2.191	1.659	2.893

jmbbaamxylsm	-0.2591	0.1062	6.0	0.0147	0.772	0.627	0.95
jmbuaamxylsm	0.9549	0.3083	9.6	0.002	2.598	1.42	4.755
jmbdaamxylsm	-0.5453	0.1037	27.6	0.0001	0.58	0.473	0.71
jmstaamxylsm	-0.0142	0.0141	1.0	0.3138	0.986	0.959	1.014
jmaaxysm	0.1812	0.0335	29.3	0.0001	1.199	1.123	1.28
jmamxsm	0.1199	0.0187	41.1	0.0001	1.127	1.087	1.169
jmptamxslm	0.2236	0.0339	43.6	0.0001	1.251	1.17	1.336
jmbaamxslm	0.74	0.1031	51.5	0.0001	2.096	1.712	2.565
jmbraamxslm	1.1974	0.3731	10.3	0.0013	3.312	1.594	6.88
jmblaamxslm	-1.2562	0.4435	8.0	0.0046	0.285	0.119	0.679
jmbfaamxslm	0.7972	0.1432	31.0	0.0001	2.219	1.676	2.938
jmbbaamxslm	-0.252	0.1059	5.7	0.0174	0.777	0.632	0.957
jmbuaamxslm	1.0862	0.2994	13.2	0.0003	2.963	1.648	5.328
jmbdaamxslm	-0.5509	0.1053	27.4	0.0001	0.576	0.469	0.709
jmstaamxslm	-0.015	0.0142	1.1	0.2908	0.985	0.958	1.013
jmamyslm	0.4645	0.0625	55.2	0.0001	1.591	1.408	1.799
jmptamyslm	-0.013	0.0452	0.1	0.7735	0.987	0.903	1.079
jmbaamyslm	0.2193	0.032	47.0	0.0001	1.245	1.17	1.326
jmbraamyslm	0.737	0.3564	4.3	0.0386	2.09	1.039	4.201
jmblaamyslm	-0.2368	0.4016	0.3	0.5554	0.789	0.359	1.734
jmbfaamyslm	0.8074	0.1435	31.7	0.0001	2.242	1.693	2.97
jmbbaamyslm	-0.0921	0.0926	1.0	0.3204	0.912	0.761	1.094
jmbuaamyslm	0.919	0.2258	16.6	0.0001	2.507	1.61	3.902
jmbdaamyslm	-0.5593	0.108	26.8	0.0001	0.572	0.463	0.706
jmstaamyslm	-0.00961	0.0148	0.4	0.5175	0.99	0.962	1.02
jmamxdlm	0.0704	0.0124	32.4	0.0001	1.073	1.047	1.099
jmptamxdlm	0.1682	0.0246	46.5	0.0001	1.183	1.127	1.242
jmbaamxdlm	0.6432	0.0901	51.0	0.0001	1.903	1.595	2.27
jmbraamxdlm	1.3083	0.3638	12.9	0.0003	3.7	1.814	7.549
jmblaamxdlm	-1.2936	0.4333	8.9	0.0028	0.274	0.117	0.641
jmbfaamxdlm	0.3556	0.0473	56.6	0.0001	1.427	1.301	1.566
jmbbaamxdlm	0.2209	0.0747	8.7	0.0031	1.247	1.077	1.444
jmbuaamxdlm	0.3283	0.0484	46.1	0.0001	1.389	1.263	1.527
jmbdaamxdlm	-0.1668	0.0385	18.7	0.0001	0.846	0.785	0.913
jmstaamxdlm	-0.011	0.0137	0.6	0.4221	0.989	0.963	1.016
jmamydlm	0.2782	0.0442	39.6	0.0001	1.321	1.211	1.44
jmptamydlm	0.1254	0.0389	10.4	0.0013	1.134	1.05	1.223
jmbaamydlm	0.2299	0.0326	49.6	0.0001	1.258	1.18	1.342
jmbraamydlm	0.4562	0.3152	2.1	0.1478	1.578	0.851	2.927
jmblaamydlm	-0.3691	0.3784	1.0	0.3293	0.691	0.329	1.451
jmbfaamydlm	0.3852	0.0557	47.8	0.0001	1.47	1.318	1.64
jmbbaamydlm	-0.048	0.0639	0.6	0.4527	0.953	0.841	1.08
jmbuaamydlm	0.3516	0.0557	39.8	0.0001	1.421	1.274	1.585
jmbdaamydlm	-0.2736	0.0596	21.1	0.0001	0.761	0.677	0.855
jmstaamydlm	-0.00676	0.0146	0.2	0.6421	0.993	0.965	1.022
jmamxyldm	0.0692	0.0121	32.9	0.0001	1.072	1.047	1.097
jmptamxyldm	0.1722	0.0248	48.1	0.0001	1.188	1.131	1.247
jmbaamxyldm	0.5149	0.0738	48.6	0.0001	1.673	1.448	1.934
jmbraamxyldm	1.2534	0.3543	12.5	0.0004	3.502	1.749	7.014
jmblaamxyldm	-1.2733	0.4275	8.9	0.0029	0.28	0.121	0.647
jmbfaamxyldm	0.3558	0.0473	56.6	0.0001	1.427	1.301	1.566

jmbbaamxyldm	0.0835	0.0784	1.1	0.2866	1.087	0.932	1.268
jmbuaamxyldm	0.3279	0.0481	46.5	0.0001	1.388	1.263	1.525
jmbdaamxyldm	-0.1493	0.0376	15.7	0.0001	0.861	0.8	0.927
jmstaamxyldm	-0.0104	0.0136	0.6	0.4458	0.99	0.964	1.016
jmaaxyldm	0.0704	0.0264	7.1	0.0077	1.073	1.019	1.13
jmamyzdbm	0.0826	0.0128	41.8	0.0001	1.086	1.059	1.114
jmptamyzdbm	0.2199	0.0334	43.4	0.0001	1.246	1.167	1.33
jmbaamyzdbm	0.8025	0.0979	67.1	0.0001	2.231	1.841	2.703
jmbraamyzdbm	0.9816	0.319	9.5	0.0021	2.669	1.428	4.987
jmblaamyzdbm	-0.5522	0.3524	2.5	0.1171	0.576	0.289	1.148
jmbfaamyzdbm	0.367	0.0489	56.4	0.0001	1.443	1.312	1.588
jmbbaamyzdbm	0.1121	0.0699	2.6	0.1088	1.119	0.975	1.283
jmbuaamyzdbm	0.3319	0.0475	48.8	0.0001	1.394	1.27	1.53
jmbdaamyzdbm	-0.1917	0.0466	17.0	0.0001	0.826	0.754	0.904
jmstaamyzdbm	-0.00952	0.0138	0.5	0.4907	0.991	0.964	1.018
jmamrdbm	0.081	0.0124	42.8	0.0001	1.084	1.058	1.111
jmptamrdbm	0.1973	0.0315	39.3	0.0001	1.218	1.145	1.296
jmbaamrdbm	0.6554	0.0833	62.0	0.0001	1.926	1.636	2.267
jmbraamrdbm	0.9457	0.3173	8.9	0.0029	2.575	1.382	4.795
jmblaamrdbm	-0.5602	0.3487	2.6	0.1082	0.571	0.288	1.131
jmbfaamrdbm	0.3658	0.0489	56.0	0.0001	1.442	1.31	1.587
jmbbaamrdbm	0.1058	0.0755	2.0	0.1613	1.112	0.959	1.289
jmbuaamrdbm	0.3293	0.0474	48.2	0.0001	1.39	1.267	1.525
jmbdaamrdbm	-0.2052	0.0467	19.3	0.0001	0.814	0.743	0.893
jmstaamrdbm	-0.00839	0.0136	0.4	0.538	0.992	0.966	1.018
jmaardbm	0.1141	0.0256	19.8	0.0001	1.121	1.066	1.179
jmamsagp	0.0127	0.0117	1.2	0.2755	1.013	0.99	1.036
jmptamsagp	0.0855	0.0147	33.9	0.0001	1.089	1.058	1.121
jmamxysmamp	0.1607	0.0535	9.0	0.0026	1.174	1.058	1.304
jmamxslmamp	0.1398	0.0558	6.3	0.0122	1.15	1.031	1.283
jmamyslmamp	-1.733	0.2866	36.6	0.0001	0.177	0.101	0.31
jmamxdlmamp	0.0134	0.0286	0.2	0.6399	1.013	0.958	1.072
jmamydlmamp	-2.3768	0.3486	46.5	0.0001	0.093	0.047	0.184
jmamyzdbmamsp	0.0218	0.0331	0.4	0.5106	1.022	0.958	1.09
jmamrmamp	0.2009	0.0345	33.8	0.0001	1.223	1.142	1.308
jmmrlatp	0.1217	0.059	4.3	0.039	1.129	1.006	1.268
jmptmrlatp	0.054	0.0422	1.6	0.2013	1.055	0.972	1.146
jmmllatp	-1.1125	0.1263	77.6	0.0001	0.329	0.257	0.421
jmptmllatp	-0.2128	0.0506	17.7	0.0001	0.808	0.732	0.893
jmmisagfv	0.0643	0.0105	37.4	0.0001	1.066	1.045	1.089
jmptmsagfv	-0.0693	0.0292	5.6	0.0177	0.933	0.881	0.988
jmmisagev	-0.0203	0.00854	5.7	0.0174	0.98	0.964	0.996
jmptmsagev	-0.0321	0.0375	0.7	0.3919	0.968	0.9	1.042
jmmisagacc	0.00612	0.00109	31.7	0.0001	1.006	1.004	1.008
jmptmsagacc	-0.2099	0.0373	31.6	0.0001	0.811	0.754	0.872
jmmisagdec	-0.00654	0.00111	34.8	0.0001	0.993	0.991	0.996
jmptmsagdec	0.0974	0.0383	6.5	0.0109	1.102	1.023	1.188
jmmrlatv	0.056	0.00967	33.5	0.0001	1.058	1.038	1.078
jmptmrlatv	-0.1382	0.0432	10.3	0.0014	0.871	0.8	0.948
jmmllatv	-0.0648	0.0103	39.6	0.0001	0.937	0.919	0.956
jmptmllatv	-0.1134	0.0504	5.1	0.0244	0.893	0.809	0.985

jmmlatacc	0.00652	0.00104	39.1	0.0001	1.007	1.004	1.009
jmptmlatacc	-0.0967	0.0428	5.1	0.0239	0.908	0.835	0.987
jmmlatdec	-0.00688	0.00109	39.9	0.0001	0.993	0.991	0.995
jmptmlatdec	-0.1575	0.0469	11.3	0.0008	0.854	0.779	0.936
jmmbxrtvel	195.3	51.8215	14.2	0.0002	***	***	***
jmptmbxrtv	-0.1365	0.048	8.1	0.0044	0.872	0.794	0.958
jmmbxleftv	-52.4404	42.8803	1.5	0.2213	***	***	***
jmptmbxleftv	-0.3336	0.0522	40.8	0.0001	0.716	0.647	0.794
jmmbxvel	44.0885	5.8518	56.8	0.0001	***	***	***
jmptmbxvel	0.0403	0.0199	4.1	0.0425	1.041	1.001	1.082
jmmbxv	-140.7	28.1589	25.0	0.0001	0.001	0.001	0.001
jmptmbxv	0.0374	0.0116	10.5	0.0012	1.038	1.015	1.062
jmmbxupv	58.1326	9.2501	39.5	0.0001	***	***	***
jmptmbxupv	0.1316	0.0211	39.0	0.0001	1.141	1.095	1.189
jmmbxdownv	-38.3067	10.6387	13.0	0.0003	0.001	0.001	0.001
jmptmbxdnv	-0.0106	0.0168	0.4	0.5283	0.989	0.958	1.023
jmambrvel	37.0274	5.0858	53.0	0.0001	***	***	***
jmptambrvel	0.1014	0.0198	26.3	0.0001	1.107	1.065	1.151
jmmbxacc	1.002	0.2609	14.7	0.0001	2.724	1.633	4.542
jmptmbxacc	-0.1144	0.0459	6.2	0.0127	0.892	0.815	0.976
jmmbxdec	-0.3042	0.2162	2.0	0.1595	0.738	0.483	1.127
jmptmbxdec	-0.345	0.0529	42.6	0.0001	0.708	0.639	0.786
jmmbyacc	0.2382	0.0312	58.4	0.0001	1.269	1.194	1.349
jmptmbyacc	0.0685	0.0198	11.9	0.0005	1.071	1.03	1.113
jmmbydec	-0.6894	0.1428	23.3	0.0001	0.502	0.379	0.664
jmptmbydec	0.0362	0.0117	9.6	0.002	1.037	1.013	1.061
jmmbzacc	0.2785	0.0382	53.1	0.0001	1.321	1.226	1.424
jmptmbzacc	0.1337	0.021	40.6	0.0001	1.143	1.097	1.191
jmmbzdec	-0.5076	0.0668	57.7	0.0001	0.602	0.528	0.686
jmptmbzdec	-0.0812	0.0233	12.2	0.0005	0.922	0.881	0.965
jmambraccng	0.1871	0.0244	59.0	0.0001	1.206	1.15	1.265
jmptambraccng	0.0679	0.0215	9.9	0.0016	1.07	1.026	1.116
jmRWL	0.6072	0.1329	20.9	0.0001	1.835	1.415	2.381
jmLI	-0.2703	0.3616	0.6	0.4548	0.763	0.376	1.55
jmbfyvel	41.7538	6.1766	45.7	0.0001	***	***	***
jsfismass	-1.49E-07	2.10E-06	0.0	0.9435	1.000	1.000	1.000
jsfidfrz	-8.57E-07	1.97E-06	0.2	0.6640	1.000	1.000	1.000
jsfiadfry	5.66E-06	5.48E-06	1.1	0.302	1.000	1.000	1.000
jsfiadyzf	2.37E-07	1.82E-06	0.0	0.8968	1.000	1.000	1.000
jsfiaxslm	-5.42E-06	7.13E-06	0.6	0.447	1.000	1.000	1.000
jsfiayslm	0.000032	0.00003	1.1	0.2903	1.000	1.000	1.000
jsfiaxyism	-3.99E-06	6.82E-06	0.3	0.5587	1.000	1.000	1.000
jsfiaxdm	-7.34E-06	6.60E-06	1.2	0.2658	1.000	1.000	1.000
jsfiaydm	0.000016	0.000028	0.3	0.5591	1.000	1.000	1.000
jsfiaxyldm	-6.00E-06	6.31E-06	0.9	0.3421	1.000	1.000	1.000
jsfiyzdbm	-2.27E-06	6.30E-06	0.1	0.7186	1.000	1.000	1.000
jsfirdbm	-1.15E-06	6.00E-06	0.0	0.8476	1.000	1.000	1.000
jsfisagp	-0.00002	6.02E-06	15.5	0.0001	1.000	1.000	1.000
jsfisagfv	0.000022	9.22E-06	5.8	0.0158	1.000	1.000	1.000
jsfisagev	0.000013	5.63E-06	5.0	0.0255	1.000	1.000	1.000
jsfisagacc	9.46E-07	8.54E-07	1.2	0.2681	1.000	1.000	1.000

jsfisagdec	-8.64E-07	8.58E-07	1.0	0.3142	1.000	1.000	1.000
jsfilatrp	-0.00012	0.000031	16.6	0.0001	1.000	1.000	1.000
jsfilatlp	-0.00016	0.000049	10.9	0.0009	1.000	1.000	1.000
jsfilatrv	-2.36E-06	7.59E-06	0.1	0.7556	1.000	1.000	1.000
jsfilatlrv	4.76E-06	7.47E-06	0.4	0.5241	1.000	1.000	1.000
jsfilatacc	-2.58E-07	8.27E-07	0.1	0.755	1.000	1.000	1.000
jsfilatdec	2.62E-07	8.22E-07	0.1	0.7496	1.000	1.000	1.000
jsfibxrvel	-0.1147	0.0415	7.6	0.0058	0.892	0.822	0.967
jsfibxlvel	0.0711	0.0278	6.5	0.0107	1.074	1.017	1.134
jsfibfyvel	0.00645	0.00629	1.1	0.305	1.006	0.994	1.019
jsfibbyvel	-2.7728	0.9864	7.9	0.0049	0.062	0.009	0.432
jsfibuzacc	-0.00544	0.00294	3.4	0.0642	0.995	0.989	1.000
jsfibdzacc	-0.7322	0.1535	22.7	0.0001	0.481	0.356	0.650
jsfibrvel	-0.00535	0.00277	3.7	0.0535	0.995	0.989	1.000
jsfibxacc	-0.00058	0.000212	7.5	0.0061	0.999	0.999	1.000
jsfibxdec	3.55E-04	1.42E-04	6.3	0.0124	1.000	1.000	1.001
jsfibyacc	3.20E-05	3.20E-05	1.0	0.3221	1.000	1.000	1.000
jsfibydec	-0.0135	0.00479	7.9	0.0049	0.987	0.977	0.996
jsfibzacc	-5.00E-05	1.19E-04	0.2	0.6669	1.000	1.000	1.000
jsfibzdec	-3.30E-04	1.08E-04	9.1	0.0025	1.000	1.000	1.000
jsfibraccng	-9.78E-06	0.000029	0.1	0.7373	1.000	1.000	1.000
jsfpdasm	3.63E-07	1.64E-06	0.0	0.8255	1.000	1.000	1.000
jsfpdadzf	1.28E-06	1.22E-06	1.1	0.295	1.000	1.000	1.000
jsfpdadyf	4.47E-06	3.18E-06	2.0	0.1599	1.000	1.000	1.000
jsfpdadyzf	1.49E-06	1.19E-06	1.6	0.2076	1.000	1.000	1.000
jsfpdaxslm	2.58E-06	4.04E-06	0.4	0.5233	1.000	1.000	1.000
jsfpdayslm	0.000034	0.000012	8.3	0.0039	1.000	1.000	1.000
jsfpdaxylsm	2.90E-06	3.93E-06	0.5	0.4604	1.000	1.000	1.000
jsfpdaxdm	4.24E-06	3.06E-06	1.9	0.1653	1.000	1.000	1.000
jsfpdaydm	0.000026	9.60E-06	7.6	0.0059	1.000	1.000	1.000
jsfpdaxylm	4.31E-06	2.96E-06	2.1	0.1458	1.000	1.000	1.000
jsfpdyzdbm	5.49E-06	3.12E-06	3.1	0.0789	1.000	1.000	1.000
jsfdrdbm	5.53E-06	3.02E-06	3.4	0.0672	1.000	1.000	1.000
jsfpdsagp	-1.41E-06	2.82E-06	0.2	0.6171	1.000	1.000	1.000
jsfpdsagv	7.15E-07	1.38E-06	0.3	0.604	1.000	1.000	1.000
jsfpdsaga	2.35E-07	1.66E-07	2.0	0.1573	1.000	1.000	1.000
jsfpdlatp	-1.86E-06	8.42E-06	0.0	0.8248	1.000	1.000	1.000
jsfpdlatv	9.96E-07	1.32E-06	0.6	0.4494	1.000	1.000	1.000
jsfpdlata	1.32E-07	1.43E-07	0.8	0.3581	1.000	1.000	1.000
jsfpdbxvel	-0.00769	0.00561	1.9	0.1705	1.000	1.000	1.000
jsfpdbyvel	0.00587	0.00152	14.8	0.0001	1.000	1.000	1.000
jsfpdbzvel	0.00275	0.00141	3.8	0.0517	1.003	1.000	1.006
jsfpdbrvel	0.00293	0.00102	8.3	0.004	1.003	1.001	1.005
jsfpdbxacc	-0.00004	0.000028	1.7	0.1898	1.000	1.000	1.000
jsfpdbyacc	0.000031	8.09E-06	14.6	0.0001	1.000	1.000	1.000
jsfpdbzacc	0.000051	0.000012	17.8	0.0001	1.000	1.000	1.000
jsfpdbraccgn	0.000025	6.51E-06	14.6	0.0001	1.000	1.000	1.000
jsfreq	-0.9521	0.1477	41.6	0.0001	0.386	0.289	0.515
mbcontrol	-0.9733	0.3158	9.5	0.0021	0.378	0.203	0.702
mbsboss	0.6427	0.3378	3.6	0.0571	1.902	0.981	3.687
mbscow	0.6129	0.431	2.0	0.1549	1.846	0.793	4.296

mbsatis	-0.7512	0.3755	4.0	0.0454	0.472	0.226	0.985
mageb	0.00895	0.0238	0.1	0.7063	1.009	0.963	1.057
mbmib	-0.1077	0.0605	3.2	0.0749	0.898	0.798	1.011
mbq3	-0.3852	0.5348	0.5	0.4713	0.68	0.239	1.941
mbq4	-0.2481	0.1364	3.3	0.069	0.78	0.597	1.02
mbq5	-0.3379	0.164	4.2	0.0394	0.713	0.517	0.984
mbq6	-0.6869	0.1925	12.7	0.0004	0.503	0.345	0.734
mbq7	-1.4267	0.3264	19.1	0.0001	0.24	0.127	0.455
mbq8	-0.7042	0.7651	0.8	0.3573	0.494	0.11	2.215

*** indicates the odds ratio was not interpretable

Table 3-10. Final models for Pn. (a) complex model; (b) simplified model

(a)

Variable Name	Cut-point	Estimate	St Error	Wald Score	P-Values	Sensitivity	Specificity
Average of the absolute maximum resultant dynamic moment (Nm)	> 44	1.3801	0.376	13.5	0.0002	70	94
Average of the maximum lateral trunk acceleration (deg/s^2)	> 992	2.4282	0.435	31.2	0.0001		
Average Duration (sec)	> 2.86	2.3997	0.385	38.9	0.0001		

(b)

Variable Name	Cut-point	Estimate	St Error	Wald Score	P-Values	Sensitivity	Specificity
Average box weight (N)	>49	0.9853	0.328	9.0	0.0026	75	81
Average Duration (sec)	>2.86	2.8016	0.329	72.5	0.0001		

The final models for Pn are shown in Table 3-10. The complex model has three variables. Absolute maximum resultant dynamic moment is from the load moment category. Average of the maximum lateral trunk acceleration across all the exertions sampled represents the kinematics variables. Duration is a temporal variable that is defined by the average length of the exertions in seconds. If the average absolute maximum resultant dynamic moment is greater than 44 Nm then the job has increased risk. If the average maximum lateral trunk acceleration exceeds 992 deg/sec² then the job has higher risk. If the average task duration is greater than 2.86 seconds then the job has increased risk. The CART cut-points quantify how much exposure is too much. The estimates are calculated given the other variables in the model and all are statistically significant. If any of the variables in the model change the estimates would change. The sensitivity of the model is 70%, while the specificity is 93.8%.

The probability of a job being high risk may be determined using equation 1 for all situations of the complex Pn model above. Table 3-11 illustrates how the probability of a job being high risk changes as a function of each variable exceeding the CART cut-points. For example, if the average absolute maximum resultant dynamic moment, average maximum lateral trunk acceleration and average task duration are all below the cut-point in Table 3-10a then the probability of the job being high risk is 0.0611. If only one of the variables is above the threshold value the probabilities ranges from between 0.2055 and 0.4246. If two of the three variables exceed the threshold the probabilities range from 0.7403 to 0.8905. If all three variables exceed the cut-point then the probability is 0.9700 of being high risk. Thus, as more variables exceed the cut-points the probability of a job being high risk becomes greater. Note that equation 1 contains the estimates from Table 3-10a therefore all the probabilities in Table 3-11 are dependent upon the multivariate nature of the model. Changing any component of the model may change the probability of a job being high risk significantly.

Eq.1

$$p = e^{(-27321 + 1.3801(x1) + 2.4282(x2) + 2.3997(x3))} / 1 + e^{(-27321 + 1.3801(x1) + 2.4282(x2) + 2.3997(x3))}$$

where: x1 = 1 if average absolute maximum resultant dynamic moment > 44 Nm, else = 0

x2 = 1 if average maximum lateral trunk acceleration > 992 deg/sec², else=0

x3 = 1 if average task duration is greater than 2.86 seconds, else=0

Table 3-11. Probability of job being high risk using the complex Pn model for all combinations of predictors.

Average Absolute Maximum Resultant Dynamic Moment	Average Maximum Lateral Trunk Acceleration	Average Task Duration	Probability (High Risk)
0	0	0	0.0611
1	0	0	0.2055
0	1	0	0.4246
0	0	1	0.4176
1	1	0	0.7458
1	0	1	0.7403
0	1	1	0.8905
1	1	1	0.9700

The final specific aim is to create a simplified model predicting high risk of disability as measured by Pn. The goal of the simplified model was to select variables that could be easily measured without complicated instrumentation. The correlation matrix in Appendix A-3 was used to help select variables. The variables selected were evaluated in CART to determine cut-points. The final simplified logistic regression model has two variables as shown in Table 3-10b. Average box weight was used as a surrogate of the averaged maximum resultant dynamic box moment, since these two variables had a correlation of 0.84. Duration was kept in the simplified model because it is easy to measure. The cut-point for average box weight was 49 N (11 lbs) and the cut-point for task duration was 2.86. The model predicts the job to be high risk with a sensitivity of 75% and a specificity of 81%. The dichotomized measures from CART have indicated how much exposure is too much for each of the variables.

The probability of a job being high risk for the simplified Pn model can be determined using equation 2. Table 3-12 illustrates how the probability of a job being high risk will change for all zero and one combination of the model variables. If both the average box weight and task duration are below the cut-point values in Table 3-10b then the probability that the job is high risk is 0.2384. If the average box weight is above 49 N and task duration is less than 2.86 seconds then the probability is 0.4561. If the average task duration exceeds 2.86 and the average box weight is below 49N then the probability of the job being high risk is 0.8376. The task duration by itself exceeding the cut-point creates a very different probability of high risk compared to average box weight by itself exceeding the cut-point. This shows that task duration contributes greatly in the simplified model to a job being high risk. Note the difference in the probability of high-risk for task duration in Table 3-11 (0.4176) and Table 3-12 (0.8376). This difference is due to the other factors in the model and illustrates the multivariate nature of the model. Finally, when both average box weight and task duration exceed the cut-point the probability of the job being high-risk is 0.9325.

Eq. 2

$$p = e^{(-1.1612 + 0.9853(x1) + 2.8016(x2))} / 1 + e^{(-1.1612 + 0.9853(x1) + 2.8016(x2))}$$

where: x1 = 1 if average box weight is greater than 49N, else = 0

x2 = 1 if average task duration is greater than 2.86 seconds, else=0

Table 3-12. Probability of job being high risk using the simplified Pn model for all combinations of predictors.

Average Box Weight	Average Task Duration	Probability (High Risk)
0	0	0.2384
1	0	0.4561
0	1	0.8376
1	1	0.9325

3.3.4.2 Statistical model for incidence rate (I200k)

When using incidence rate (I200k) as the outcome variable, high risk jobs were defined as those jobs associated with at least 12 low back injuries per 200,000 hours of exposure. Low risk jobs were defined as those jobs with records showing no injuries for 3 years. These definitions are consistent with those used in previous research (Marras, Lavender,

Leurgans, Rajulu, Allread, Fathallah, & Ferguson, 1993). Based on those definitions, 15 high risk jobs and 15 low risk jobs were identified. Jobs not fitting into either of these two groups or with less than or equal to two workers at follow-up were removed from the analysis.

Univariate logistic regression results for incidence rate are shown in Table 3-13. The logistic regression models were weighted based on the number of workers at follow-up. The same approach for the Pn model development was used to build the final models for I200k. Table 3-13 lists the odds ratio for job mean absolute average XY static moment (jmaaxysm) as 1.190. This indicates that for every 1N*m increase in job mean absolute average XY static moment that the odds ratio will increase exponentially ($e^{0.1741 \cdot \text{XY static lift moment}}$). The table lists job mean absolute average XY lift dynamic lift moment (jmaaxyldlm) as 1.228. Thus, the odds ratio for the dynamic measure is greater than that of the static suggesting greater risk for dynamic rather static absolute average moment for I200k. Many of the odds ratios for the integrated measures are 1.00 because the estimates are very small and the actual values of the integrated measure across the day are very large. However, based on the Wald Score and p-values many of these factors are statistically significant. For example integrated static mass, all dynamic forces, static moments and dynamic forces all have p-values of 0.0001 in Table 3-13.

Table 3-13. Univariate logistic regression for incidence rate (I200k).

Variable Name	Estimate	St Error	Wald Score	P-Values	Odds Ratio	95% Confidence Interval	
jmduration	0.2333	0.1686	1.9	0.1665	1.263	0.907	1.757
jmdurationne	-0.0486	0.0157	9.5	0.002	0.953	0.924	0.982
jsfduration	0.000758	0.000203	14.0	0.0002	1.001	1.000	1.001
jsfdurationne	-0.00003	0.000045	0.5	0.496	1.000	1.000	1.000
jtduration	7.72E-06	0.000039	0.0	0.8433	1.000	1.000	1.000
jmaxxyma	4.7243	3.409	1.9	0.1658	***	***	***
jmntmaxxyma	-0.0949	0.023	17.0	0.0001	0.91	0.869	0.951
jmsxyma	4.5337	3.9727	1.3	0.2538	***	***	***
jmexyma	-2.4711	3.5515	0.5	0.4866	0.084	0.001	89.096
jmmresma	1.5864	2.9212	0.3	0.5871	***	***	***
jmntmresma	-0.0323	0.0166	3.8	0.0523	0.968	0.937	1.000
jmsboxh	-1.1294	1.469	0.6	0.442	0.323	0.018	5.754
jmeboxh	4.9958	1.2263	16.6	0.0001	***	***	***
jmsasym	0.3047	0.0744	16.8	0.0001	1.356	1.172	1.569
jmeasym	0.00234	0.0663	0.0	0.9719	1.002	0.880	1.141
jmasmass	0.0527	0.0139	14.5	0.0001	1.054	1.026	1.083
jmaxdz	0.0337	0.00725	21.7	0.0001	1.034	1.020	1.049
jmntmaxdz	-0.0285	0.0232	1.5	0.2203	0.972	0.929	1.017
jmavedz	0.0612	0.0134	20.8	0.0001	1.063	1.036	1.091
jmamaxdy	0.132	0.0205	41.6	0.0001	1.141	1.096	1.188
jmntamaxdy	0.1062	0.0428	6.2	0.013	1.112	1.023	1.209
jmamaxdyz	0.0413	0.00722	32.8	0.0001	1.042	1.028	1.057
jmntamaxdyz	-0.039	0.0249	2.5	0.1175	0.962	0.916	1.01
jmamxylsm	0.1056	0.0209	25.5	0.0001	1.111	1.067	1.158
jmntamxylsm	-0.1406	0.0277	25.8	0.0001	0.869	0.823	0.917

jmbaamxylsm	0.3906	0.079	24.4	0.0001	1.478	1.266	1.725
jmbraamxylsm	2.6295	0.6502	16.4	0.0001	13.867	3.877	49.599
jmblaamxylsm	-1.6963	0.6601	6.6	0.0102	0.183	0.050	0.669
jmbfaamxylsm	1.2842	0.2189	34.4	0.0001	3.612	2.352	5.547
jmbbaamxylsm	-0.0481	0.0838	0.3	0.566	0.953	0.809	1.123
jmbuaamxylsm	2.787	0.5452	26.1	0.0001	16.233	5.576	47.254
jmbdaamxylsm	0.151	0.113	1.8	0.1814	1.163	0.932	1.451
jmstaamxylsm	-0.0252	0.0178	2.0	0.157	0.975	0.942	1.010
jmaaxysm	0.1741	0.0372	21.9	0.0001	1.190	1.106	1.280
jmamxsm	0.106	0.0214	24.6	0.0001	1.112	1.066	1.159
jmptamxslm	-0.1445	0.0278	27.0	0.0001	0.865	0.820	0.914
jmbaamxslm	0.352	0.0900	15.3	0.0001	1.422	1.192	1.696
jmbraamxslm	2.4064	0.6382	14.2	0.0002	11.094	3.176	38.754
jmblaamxslm	-1.4901	0.6639	5.0	0.0248	0.225	0.061	0.828
jmbfaamxslm	1.2875	0.2204	34.1	0.0001	3.624	2.352	5.582
jmbbaamxslm	-0.0415	0.0914	0.2	0.6500	0.959	0.802	1.148
jmbuaamxslm	2.3392	0.5035	21.6	0.0001	10.373	3.866	27.830
jmbdaamxslm	0.1477	0.1137	1.7	0.1941	1.159	0.928	1.449
jmstaamxslm	-0.0244	0.0179	1.9	0.1731	0.976	0.942	1.011
jmamyslm	0.3109	0.0585	28.2	0.0001	1.365	1.217	1.531
jmptamyslm	-0.1106	0.0612	3.3	0.0704	0.895	0.794	1.009
jmbaamyslm	0.2103	0.0377	31.1	0.0001	1.234	1.146	1.329
jmbraamyslm	2.4351	0.6529	13.9	0.0002	11.417	3.175	41.051
jmblaamyslm	-1.6927	0.5786	8.6	0.0034	0.184	0.059	0.572
jmbfaamyslm	1.1812	0.2087	32.0	0.0001	3.258	2.164	4.905
jmbbaamyslm	-0.5894	0.1169	25.4	0.0001	0.555	0.441	0.698
jmbuaamyslm	3.4335	0.5853	34.4	0.0001	30.985	9.839	97.58
jmbdaamyslm	0.0735	0.1214	0.4	0.5446	1.076	0.848	1.365
jmstaamyslm	-0.0231	0.018	1.6	0.2001	0.977	0.943	1.012
jmamxdlm	0.0716	0.015	22.7	0.0001	1.074	1.043	1.106
jmptamxdlm	-0.0631	0.0201	9.8	0.0017	0.939	0.903	0.977
jmbaamxdlm	0.3104	0.0837	13.8	0.0002	1.364	1.158	1.607
jmbraamxdlm	2.3553	0.5712	17.0	0.0001	10.541	3.441	32.29
jmblaamxdlm	-1.5979	0.6179	6.7	0.0097	0.202	0.060	0.679
jmbfaamxdlm	0.057	0.0377	2.3	0.1304	1.059	0.983	1.14
jmbbaamxdlm	-0.5902	0.1001	34.8	0.0001	0.554	0.456	0.674
jmbuaamxdlm	0.0347	0.0382	0.8	0.3639	1.035	0.961	1.116
jmbdaamxdlm	-0.1841	0.0439	17.6	0.0001	0.832	0.763	0.907
jmstaamxdlm	-0.0293	0.0171	2.9	0.0864	0.971	0.939	1.004
jmamydlm	0.283	0.0514	30.3	0.0001	1.327	1.200	1.468
jmptamydlm	-0.0601	0.0381	2.5	0.1153	0.942	0.874	1.015
jmbaamydlm	0.1805	0.0361	25.1	0.0001	1.198	1.116	1.286
jmbraamydlm	1.8404	0.5323	12.0	0.0005	6.299	2.219	17.881
jmblaamydlm	-1.3114	0.5351	6.0	0.0143	0.269	0.094	0.769
jmbfaamydlm	0.1293	0.0529	6.0	0.0146	1.138	1.026	1.263
jmbbaamydlm	-0.3971	0.0726	29.9	0.0001	0.672	0.583	0.775
jmbuaamydlm	0.0613	0.0472	1.7	0.1942	1.063	0.969	1.166
jmbdaamydlm	-0.06	0.0769	0.6	0.4352	0.942	0.810	1.095
jmstaamydlm	-0.0237	0.0175	1.8	0.1746	0.977	0.944	1.011
jmamxyldm	0.071	0.0147	23.4	0.0001	1.074	1.043	1.105
jmptamxyldm	-0.0604	0.0198	9.3	0.0023	0.941	0.906	0.979

jmbaamxyldm	0.2915	0.0734	15.8	0.0001	1.338	1.159	1.546
jmbraamxyldm	2.5111	0.5855	18.4	0.0001	12.318	3.910	38.808
jmblaamxyldm	-1.724	0.6151	7.9	0.0051	0.178	0.053	0.596
jmbfaamxyldm	0.0571	0.0375	2.3	0.1283	1.059	0.984	1.14
jmbbaamxyldm	-0.4108	0.0925	19.7	0.0001	0.663	0.553	0.795
jmbuaamxyldm	0.0313	0.0381	0.7	0.4115	1.032	0.958	1.112
jmbdaamxyldm	-0.2046	0.0441	21.5	0.0001	0.815	0.747	0.889
jmstaamxyldm	-0.0312	0.0171	3.3	0.068	0.969	0.937	1.002
jmaaxyldm	0.205	0.0374	30.1	0.0001	1.228	1.141	1.321
jmamyzdbm	0.0772	0.0149	26.9	0.0001	1.08	1.049	1.112
jmptamyzdbm	-0.0554	0.0272	4.2	0.0416	0.946	0.897	0.998
jmbaamyzdbm	0.2707	0.0836	10.5	0.0012	1.311	1.113	1.544
jmbraamyzdbm	2.6245	0.5374	23.9	0.0001	13.798	4.813	39.56
jmblaamyzdbm	-1.7689	0.5247	11.4	0.0007	0.171	0.061	0.477
jmbfaamyzdbm	0.0622	0.0384	2.6	0.1053	1.064	0.987	1.147
jmbbaamyzdbm	-0.4718	0.1018	21.5	0.0001	0.624	0.511	0.762
jmbuaamyzdbm	0.0367	0.0378	0.9	0.331	1.037	0.963	1.117
jmbdaamyzdbm	-0.1509	0.0514	8.6	0.0033	0.86	0.778	0.951
jmstaamyzdbm	-0.0424	0.0176	5.8	0.0159	0.958	0.926	0.992
jmamrdbm	0.0771	0.0145	28.2	0.0001	1.08	1.050	1.111
jmptamrdbm	-0.0529	0.026	4.1	0.0422	0.948	0.901	0.998
jmbaamrdbm	0.259	0.0742	12.2	0.0005	1.296	1.120	1.498
jmbraamrdbm	2.4737	0.5253	22.2	0.0001	11.866	4.238	33.226
jmblaamrdbm	-1.7304	0.5257	10.8	0.001	0.177	0.063	0.497
jmbfaamrdbm	0.0564	0.0383	2.2	0.1413	1.058	0.981	1.14
jmbbaamrdbm	-0.4187	0.0993	17.8	0.0001	0.658	0.542	0.799
jmbuaamrdbm	0.0331	0.0377	0.8	0.3794	1.034	0.96	1.113
jmbdaamrdbm	-0.1569	0.0518	9.2	0.0025	0.855	0.772	0.946
jmstaamrdbm	-0.0457	0.0176	6.7	0.0097	0.955	0.923	0.989
jmaardbm	0.2028	0.0343	34.9	0.0001	1.225	1.145	1.310
jmamsagp	-0.0219	0.0152	2.1	0.1489	0.978	0.95	1.008
jmptamsagp	-0.0714	0.0141	25.6	0.0001	0.931	0.906	0.957
jmamxysmamp	0.2609	0.0582	20.1	0.0001	1.298	1.158	1.455
jmamxslmamp	0.2634	0.0598	19.4	0.0001	1.301	1.158	1.463
jmamyslmamp	-1.0635	0.3077	11.9	0.0005	0.345	0.189	0.631
jmamxdlmamp	0.0847	0.037	5.3	0.0219	1.088	1.012	1.17
jmamydlmamp	-0.8412	0.2578	10.6	0.0011	0.431	0.26	0.715
jmamyzdbmamsp	0.0108	0.0339	0.1	0.7508	1.011	0.946	1.08
jmamrmamp	0.125	0.0355	12.4	0.0004	1.133	1.057	1.215
jmmrlatp	0.0174	0.0569	0.1	0.7594	1.018	0.91	1.138
jmptmrlatp	-0.0784	0.0508	2.4	0.123	0.925	0.837	1.021
jmmllatp	0.0716	0.0672	1.1	0.2867	1.074	0.942	1.225
jmptmllatp	0.0523	0.0385	1.8	0.1752	1.054	0.977	1.136
jmm sagfv	-0.0182	0.0091	4.0	0.0454	0.982	0.965	1.000
jmptmsagfv	-0.095	0.033	8.3	0.004	0.909	0.852	0.97
jmm sagev	-0.0121	0.00994	1.5	0.2216	0.988	0.969	1.007
jmptmsagev	0.0502	0.0374	1.8	0.1793	1.051	0.977	1.131
jmm sagacc	-0.00006	0.00102	0.0	0.9498	1.000	0.998	1.002
jmptmsagacc	-0.0396	0.0347	1.3	0.2528	0.961	0.898	1.029
jmm sagdec	-0.00068	0.00101	0.4	0.5039	0.999	0.997	1.001
jmptmsagdec	-0.0663	0.0374	3.1	0.0764	0.936	0.87	1.007

jmmrlatv	-0.00876	0.0088	1.0	0.3194	0.991	0.974	1.009
jmptmrlatv	-0.2237	0.0577	15.0	0.0001	0.800	0.714	0.895
jmmllatv	0.0114	0.00887	1.6	0.200	1.011	0.994	1.029
jmptmllatv	-0.0763	0.0547	1.9	0.1628	0.927	0.832	1.031
jmmllatacc	-0.00123	0.000923	1.8	0.1815	0.999	0.997	1.001
jmptmllatacc	-0.0756	0.0545	1.9	0.1659	0.927	0.833	1.032
jmmllatdec	0.00094	0.000927	1.0	0.3102	1.001	0.999	1.003
jmptmllatdec	-0.1847	0.0604	9.3	0.0022	0.831	0.739	0.936
jmmbxrtvel	188.7	67.0017	7.9	0.0049	***	***	***
jmptmbxrtv	0.00323	0.0334	0.0	0.9229	1.003	0.940	1.071
jmmbxleftv	-25.9722	49.4242	0.3	0.5992	***	***	***
jmptmbxleftv	-0.1473	0.0433	11.6	0.0007	0.863	0.793	0.939
jmmbxvel	11.0633	4.5376	5.9	0.0148	***	***	***
jmptmbxvel	-0.0438	0.0217	4.1	0.0434	0.957	0.917	0.999
jmmbxv	-79.0816	23.9182	10.9	0.0009	0.001	0.001	0.001
jmptmbxv	0.00675	0.00997	0.5	0.4984	1.007	0.987	1.027
jmmbxupv	6.734	6.0512	1.2	0.2658	***	***	***
jmptmbxupv	-0.0216	0.0166	1.7	0.1923	0.979	0.947	1.011
jmmbxdownv	-111.3	17.0196	42.8	0.0001	0.001	0.001	0.001
jmptmbxdnv	0.0047	0.0174	0.1	0.7872	1.005	0.971	1.04
jmambv	6.4232	3.6007	3.2	0.0744	***	***	***
jmptambv	-0.0292	0.0181	2.6	0.1073	0.971	0.937	1.006
jmmbxacc	0.9397	0.3363	7.8	0.0052	2.559	1.324	4.947
jmptmbxacc	-0.00033	0.0325	0.0	0.9919	1.000	0.938	1.065
jmmbxdec	-0.1616	0.2519	0.4	0.5212	0.851	0.519	1.394
jmptmbxdec	-0.1677	0.0461	13.2	0.0003	0.846	0.773	0.926
jmmbyacc	0.0671	0.0254	7.0	0.0081	1.069	1.018	1.124
jmptmbyacc	-0.0288	0.0197	2.1	0.1443	0.972	0.935	1.010
jmmbydec	-0.3761	0.1183	10.1	0.0015	0.687	0.545	0.866
jmptmbydec	0.00567	0.0101	0.3	0.574	1.006	0.986	1.026
jmmbzacc	0.0436	0.0297	2.2	0.1425	1.045	0.985	1.107
jmptmbzacc	-0.00943	0.0155	0.4	0.5432	0.991	0.961	1.021
jmmbzdec	-0.2062	0.0731	8.0	0.0048	0.814	0.814	0.939
jmptmbzdec	-0.0589	0.0243	5.9	0.0156	0.943	0.899	0.989
jmambzaccng	0.0438	0.0194	5.1	0.0241	1.045	1.006	1.085
jmptambzaccng	-0.0403	0.0217	3.5	0.0627	0.96	0.921	1.002
jmRWL	-0.2503	0.1317	3.6	0.0574	0.779	0.601	1.008
jmLI	2.6615	0.5243	25.8	0.0001	14.317	5.124	40.004
jmbfyvel	11.9035	4.5424	6.9	0.0088	***	***	***
jsfismass	1.70E-05	3.63E-06	21.9	0.0001	1.000	1.000	1.000
jsfidfrz	1.70E-05	3.58E-06	23.9	0.0001	1.000	1.000	1.000
jsfiadfry	6.10E-05	9.11E-06	44.6	0.0001	1.000	1.000	1.000
jsfiadyzf	0.000018	3.28E-06	30.8	0.0001	1.000	1.000	1.000
jsfiaxslm	5.70E-05	1.10E-05	26.8	0.0001	1.000	1.000	1.000
jsfiayslm	0.000299	0.000053	31.5	0.0001	1.000	1.000	1.000
jsfiaxyism	5.60E-05	1.10E-05	27.3	0.0001	1.000	1.000	1.000
jsfiaxdm	-3.00E-05	9.02E-06	14.9	0.0001	1.000	1.000	1.000
jsfiaydm	0.000291	0.000051	32.5	0.0001	1.000	1.000	1.000
jsfiaxyldm	5.50E-05	1.00E-05	29.1	0.0001	1.000	1.000	1.000
jsfiyzdbm	6.00E-05	1.00E-05	33.7	0.0001	1.000	1.000	1.000
jsfirdbm	5.80E-05	9.86E-06	34.3	0.0001	1.000	1.000	1.000

jsfisagp	0.000016	6.47E-06	6.0	0.0142	1.000	1.000	1.000
jsfisagfv	0.000012	0.000012	0.9	0.3362	1.000	1.000	1.000
jsfisagev	-0.00002	7.65E-06	8.2	0.0042	1.000	1.000	1.000
jsfisagacc	4.13E-06	1.37E-06	9.1	0.0026	1.000	1.000	1.000
jsfisagdec	-4.78E-06	1.41E-06	11.6	0.0007	1.000	1.000	1.000
jsfilatrp	0.000102	0.000037	7.5	0.0061	1.000	1.000	1.000
jsfilatlp	-0.00015	0.00007	4.5	0.0343	1.000	1.000	1.000
jsfilatrv	0.000025	0.000011	5.6	0.0178	1.000	1.000	1.000
jsfilativ	-0.00003	0.00001	8.0	0.0048	1.000	1.000	1.000
jsfilatacc	2.91E-06	1.16E-06	6.2	0.0126	1.000	1.000	1.000
jsfilatdec	-3.09E-06	1.17E-06	7.0	0.0083	1.000	1.000	1.000
jsfibxrvl	0.2039	0.0524	15.1	0.0001	1.226	1.106	1.359
jsfibxlvel	-0.1001	0.0384	6.8	0.0092	0.905	0.839	0.976
jsfibfyvel	0.0484	0.00949	26.0	0.0001	1.050	1.030	1.069
jsfibbyvel	-1.7826	0.9909	3.2	0.072	0.168	0.024	1.173
jsfibuzacc	0.0165	0.00436	14.4	0.0002	1.017	1.008	1.025
jsfibdzacc	-0.3851	0.1977	3.8	0.0515	0.68	0.462	1.002
jsfibrvel	0.0137	0.0039	12.4	0.0004	1.014	1.006	1.022
jsfibxacc	0.00104	0.00027	15.1	0.0001	1.001	1.001	1.002
jsfibxdec	-0.00052	0.00020	7.0	0.0083	0.999	0.999	1.000
jsfibyacc	0.00025	4.90E-05	26.1	0.0001	1.000	1.000	1.000
jsfibydec	-0.00861	0.00483	3.2	0.0746	0.991	0.982	1.001
jsfibzacc	8.53E-04	1.89E-04	20.3	0.0001	1.001	1.000	1.001
jsfibzdec	1.70E-05	1.24E-04	0.0	0.8912	1.000	1.000	1.000
jsfibraccng	1.70E-04	0.000041	17.1	0.0001	1.000	1.000	1.000
jsfpdasm	1.50E-05	2.88E-06	26.1	0.0001	1.000	1.000	1.000
jsfpdadzf	1.20E-05	2.25E-06	27.2	0.0001	1.000	1.000	1.000
jsfpdadyf	3.30E-05	5.27E-06	39.6	0.0001	1.000	1.000	1.000
jsfpdadyzf	1.20E-05	2.15E-06	31.1	0.0001	1.000	1.000	1.000
jsfpdaxslm	3.70E-05	6.84E-06	29.5	0.0001	1.000	1.000	1.000
jsfpdayslm	0.000127	0.000021	34.9	0.0001	1.000	1.000	1.000
jsfpdaxylsm	3.70E-05	6.69E-06	29.9	0.0001	1.000	1.000	1.000
jsfpdaxdm	3.00E-05	5.37E-06	31.1	0.0001	1.000	1.000	1.000
jsfpdaydm	0.000111	1.90E-05	36.1	0.0001	1.000	1.000	1.000
jsfpdaxylm	2.90E-05	5.23E-06	31.5	0.0001	1.000	1.000	1.000
jsfpdyzdbm	3.20E-05	5.49E-06	33.7	0.0001	1.000	1.000	1.000
jsfdrdbm	3.10E-05	5.34E-06	34.3	0.0001	1.000	1.000	1.000
jsfpdsagp	7.10E-06	3.61E-06	3.9	0.0492	1.000	1.000	1.000
jsfpdsagv	4.29E-06	2.06E-06	4.3	0.0375	1.000	1.000	1.000
jsfpdsaga	6.87E-07	2.56E-07	7.2	0.0072	1.000	1.000	1.000
jsfpdlatp	3.10E-05	1.20E-05	6.6	0.01	1.000	1.000	1.000
jsfpdlatv	3.48E-06	1.87E-06	3.5	0.063	1.000	1.000	1.000
jsfpdlata	4.23E-07	2.09E-07	4.1	0.0425	1.000	1.000	1.000
jsfpdbxvel	0.0247	0.00883	7.9	0.0051	1.025	1.007	1.043
jsfpdbyvel	0.00764	0.00225	11.6	0.0007	1.008	1.003	1.012
jsfpdbzvel	0.00602	0.0021	8.2	0.0042	1.006	1.002	1.01
jsfpdbrvl	0.00474	0.00153	9.6	0.0019	1.005	1.002	1.008
jsfpdbxacc	0.000125	0.000045	7.8	0.0052	1.000	1.000	1.000
jsfpdbyacc	0.000044	1.20E-05	13.1	0.0003	1.000	1.000	1.000
jsfpdbzacc	0.000042	0.000016	7.2	0.0071	1.000	1.000	1.000
jsfpdbaccgn	0.000031	9.52E-06	10.9	0.001	1.000	1.000	1.000

jfreq	0.2033	0.1186	2.9	0.0866	1.225	0.971	1.546
mbcontrol	-0.1048	0.3223	0.1	0.7451	0.901	0.479	1.694
mbsboss	-1.392	0.444	9.8	0.0017	0.249	0.104	0.593
mbscow	-1.7043	0.4365	15.2	0.0001	0.182	0.077	0.428
mbsatis	-1.2218	0.4324	8.0	0.0047	0.295	0.126	0.688
mageb	-0.0986	0.0326	9.1	0.0025	0.906	0.85	0.966
mbmib	0.3295	0.085	15.0	0.0001	1.390	1.177	1.642
mbq3	0.7128	0.5728	1.5	0.2134	2.04	0.664	6.268
mbq4	0.5297	0.168	9.9	0.0016	1.698	1.222	2.361
mbq5	0.4781	0.2065	5.4	0.0206	1.613	1.076	2.418
mbq6	0.4012	0.1948	4.2	0.0395	1.494	1.02	2.188
mbq7	1.3864	0.3818	13.2	0.0003	4	1.893	8.455
mbq8	1.6794	0.7951	4.5	0.0347	5.362	1.129	25.478

*** indicates the odds ratio was not interpretable

The final models for incidence rate (I200k) are included in Table 3-14. The complex model contains three variables. The load moment variable is the average of the absolute value of the horizontal (XY) dynamic lift moment. If this moment is greater than 16.8 Nm, the job has a higher risk. The kinematics category is represented by the integrated lateral acceleration. Since this variable has been scaled up to a 7-hour work period, the cut-point value is very high. As an aid to thinking about this value, this is equivalent to the subject experiencing an average lateral acceleration of 69.6 deg/s² during every exertion. Instead of using the duration of the lifting exertions as in the Pn model, the mean duration of non-load exposure or rest time was included in the final I200K model. There is a higher risk if the rest period between exertions is less than 24 seconds. This model has a sensitivity of 80% and a specificity of 87%.

The probability of a job being high risk can be determined using equation 3 from the I200k final complex model. Table 3-15 illustrates how the probability of the job being high risk will change for all zero and one combinations on model variables. If average absolute xy dynamic lift moment and integrated lateral acceleration are below the cut-point and duration of non-load exposure is greater than the cut-point, then the probability of the job being high risk is 0.0079. If either the integrated lateral acceleration or duration crosses the cut-point the probability of the job being high risk is low. It is interesting to note that if only average absolute xy dynamic lift moment is greater than the cut-point then the probability is 0.2902 compared to if the integrated lateral acceleration is above the cut-point and the duration of the non-load exposure is less than cut-point the probability is 0.1688. Thus, the average absolute xy dynamic lift moment creates greater risk by itself than the combination of integrated lateral acceleration and duration of non-load exposure. If all three variables cross the cut-point then the probability of the job being high risk is 0.9127. This would clearly create a high risk job situation. The probabilities in the model are dependent upon the other variables in the model and should be considered collectively.

Eq.3

$$p = e^{(-4.8364 + 3.9419(x1) + 1.5179(x2) + 1.7242(x3))} / 1 + e^{(-4.8364 + 3.9419(x1) + 1.5179(x2) + 1.7242(x3))}$$

where : x1 = 1 if average absolute xy dynamic lift moment > 16.8, else =0

x2 = 1, if sum of integrated lateral acceleration across day > 261242, else=0

x3 = 1, if average duration of non-load exposure < 24, else = 0

Table 3-14. Final models for incidence rate (I200k). (a) complex model; (b) simplified model.

(a)

Variable Name	Cut-point	Estimate	St Error	Wald Score	P-Values	Sensitivity	Specificity
Absolute average XY dynamic lift moment (Nm)	>16.8	3.942	0.567	48.3	0.0001	80	87
Job average Integrated lateral acceleration (deg/sec^2)	>261242	1.518	0.678	5.0	0.0252		
Job average duration of non-load exposure (sec)	<24	1.724	0.706	6.0	0.0146		

(b)

Variable Name	Cut-point	Estimate	St Error	Wald Score	P-Values	Sensitivity	Specificity
Job averaged maximum XY static lift moment (Nm)	>32	3.043	0.446	46.6	0.0001	67	93
Job average duration of non-load exposure (sec)	<24	3.385	0.494	47.0	0.0001		

Table 3-15. Probability of the job being high risk using the complex I200k model for all combinations of predictors.

Average Absolute XY Dynamic Lift Moment	Sum across day of Integrated Lateral Acceleration	Average Duration of Non-Load Exposure	Probability (High Risk)
0	0	0	0.0079
1	0	0	0.2902
0	1	0	0.0349
0	0	1	0.0429
1	1	0	0.6520
1	0	1	0.6963
0	1	1	0.1688
1	1	1	0.9127

The simplified model for I200k as shown in Table 3-14b has two variables. Many variables that were correlated with the average horizontal (XY) dynamic lift moment were selected from the correlation matrix and tried in the model. The maximum horizontal (XY) static lift moment seemed to give a better model than other variables tried. The correlation between the average horizontal dynamic lift moment and the maximum horizontal static lift moment was 0.87. The duration of non-load exposure was kept in the simplified model. When the maximum horizontal static moment is greater than 32 Nm and the rest period between exertions is less than 24 seconds, a modeled job would be identified as high risk with a sensitivity of 67% and a specificity of 93%.

The probability of the job being high risk for the simplified I200k model can be determined using equation 4. Table 3-16 shows how the probability of the job being high risk will change for all zero and one combinations of the variables. If both the average maximum xy static lift moment and average duration of non-load exposure do not cross the cut-point values the probability is only 0.0207 of the job being high risk. If either the average maximum xy static lift moment or average duration of non-load exposure crosses the cut-point value the probability of high risk is 0.3071 and 0.3842, respectively. If both measures cross the cut-point then the job would clearly be high risk with a probability of 0.9290. The probabilities are dependent upon the other variables in the model. This influence of the other variables in the model can be demonstrated by comparing the probability of the non-load exposure in the complex and simplified I200k models. In the complex model the duration of the non-load exposure by itself has a probability of 0.0429 compared to 0.3842 in the simplified model. Thus the probabilities in the tables must be thought of collectively and contingent upon the other variables in the model.

Eq. 4

$$p = e^{(-3.8566 + 3.0427(x1) + 3.3849(x2))} / 1 + e^{(-3.8566 + 3.0427(x1) + 3.3849(x2))}$$

where: x1 = 1 if maximum XY static lift moment (Nm) > 32 else = 0
x2 = 1 if the duration of non-load exposure (sec) < 24 else = 0

Table 3-16. Probability of the job being high risk using the simplified I200k model for all combinations of predictors.

Average Maximum XY Static Lift Moment	Average Duration of Non- Load Exposure	Probability (High Risk)
0	0	0.0207
1	0	0.3071
0	1	0.3842
1	1	0.9290

4. Discussion

As low back disorders continue to be the most common and significant work-related musculoskeletal disorders in the US, identifying the risk factors related to back injury has become more important. The biggest challenge facing injury prevention efforts is determining what constitute a “safe” physical workload from both the magnitude and temporal aspects. This prospective study involved 888 manual materials handling workers on 50 jobs in 21 distribution centers. Biomechanical load exposure data were measured via a Moment Exposure Tracking System on 195 workers. Health effect data were collected for back injury rates and the Clinical Lumbar Motion Monitor functional performance test. There were five specific aims in this study: 1) To develop new models based on an existing industrial exposure database, 2) To develop instrumentation so that the horizontal distance between the hands and the spine can be accurately measured for each lift performed over the course of an entire work shift, 3) To develop a database that contains the load moment exposures, hand position data, duty cycle parameters, and injury experience data, 4) To define via a prospective study the relationship between moment exposure parameters and the low back disorder incidence rates and disability measures, and 5) To develop a simplified approach that can be used by practitioners to easily evaluate work tasks.

The first specific aim to develop new models based on an existing manufacturing exposure database was achieved by using a powerful statistic software-CART. This software has helped us build a better model based on the original variables. Instead of treating the variables selected as continuous variables, CART chose a cut-point for each variable in this new model. There are several advantages related to dichotomizing variables. First, this method has increased the point estimates of odds ratios for all the variables. For example, the odds ratio for peak moment increased from 1.025 to 21.127. This suggests that moment is a very important variable, which contributes to the risk of low back injury. Second, the sensitivity and specificity of the model have been improved. With a better specificity, the model has a lower Type I error (false positive) rate. Third, using cut-points is easier for practitioners to use for risk assessment purposes. The CART model provides a threshold value for each variable, which is easily understandable for practitioners. This model reinforced the belief that the moment information is a very powerful indicator of low back disorder risk in manual materials handling environments.

The second specific aim was to develop instrumentation so that the horizontal distance between the hands and the spine can be accurately measured for each lift performed over the course of an entire work shift. A Moment Exposure Tracking System was developed to not only measure the horizontal distance between the hands and the spine (moment arm), but also the load weight, dynamic hand forces, trunk kinematics, box kinematics, and duration of exertions and rest period. The accuracy of the system has been validated using a laboratory-based magnetic motion capture system. Traditional hand measurement error of moment arm averaged 4.3 inches. The goal was to reduce of measurement error to less than 2.5 inches. A series of tests showed that the accuracy of METS reached 1.5 inches with an R^2 of 0.98. This has greatly exceeded the accuracy of the traditional tape measure method. The accuracy of the load measurement was also within one pound. The

system was designed to be able to store data for an entire work shift on a flash card. The data for each lift can also be viewed in real time on a laptop computer.

This new instrumentation significantly improved our ability to collect accurate physical exposure data in distribution center jobs. It has been successfully used to monitor 195 people in a very dynamic working environment. It allowed us to obtain biomechanical data that were not possible to measure with traditional methods. For example, in the past the load of each box handled by the workers can only be weighed to get the static load. Recent studies have indicated that static assessments may grossly under represent the loading of the tissue (Granata & Marras, 1999; Marras & Granata, 1997; Granata & Marras, 1995; Marras, 1992). METS is capable of measuring dynamic hand forces in both the lifting/lowering and push/pull directions. Therefore, dynamic load moment can be calculated for each lift. This provides us the opportunity to assess the true load moment exposures of the job.

Because the data are automatically measured and recorded by the system, there is little interruption of the worker's job. This is especially beneficial in the fast-paced distribution center environment, because continuous data collection is essential to the assessment of cumulative exposure and duty cycle variables. METS is the first system that can measure load, force, moment, kinematics, and temporal parameters of the job simultaneously. The amount of information that can be collected is enormous. It has greatly helped us to get more insight into the exposure characteristics of manual materials handling jobs.

The third specific aim was to develop a database that contains the load moment exposures, hand position data, duty cycle parameters, and injury experience data. A database that has all the above information collected from 195 distribution center workers was built. There were a total of 227 load moment exposure variables for each of the 66854 exertions. The definitions of variables, distribution plots, and the correlations among those variables can be found in the Appendices. With such a huge database, the characteristics of the physical exposure of the jobs examined can be further analyzed.

One of the observed characteristics was the difference between the static and dynamic measures. The maximum dynamic Z force (lifting force) is greater than the maximum box weight. The dynamic moments are all greater than the static moments, especially for the X-axis dynamic moment. This is because the X-axis dynamic moment results from the worker accelerating the load towards its destination instead of merely holding it statically. These results indicated that dynamic measures better represented the true load moment exposure the workers experienced, while the static parameters underestimated the exposure level.

The database also showed that there was significant amount of trunk movements during the MMH exertions. The average maximum sagittal trunk angle observed in the current study was 50.3 degrees. The maximum sagittal and lateral trunk velocities were about 70-80 deg/s. The maximum sagittal and lateral accelerations were also very high. These findings suggest that MMH jobs in the distribution center involve considerable trunk forward bending and quick motions. Therefore, workers in the distribution industry have a very high physical exposure level to risk factors of LBD. Trunk kinematics variables

should be taken into account when developing risk assessment models. It is also noticeable that lateral trunk accelerations were significantly higher than forward bending and extension accelerations. They may have a more important role as risk factors for LBD.

The fourth specific aim to define via a prospective study the relationship between moment exposure parameters and the low back disorder incidence rates and disability measures was examined by developing multiple logistic regression models for both the incidence rate (I200k) and change in low back functional performance (Pn). Since there were many significant variables in the univariate analysis, and given that the final model should not be over-specified, it would be impossible to test all the combinations of the significant variables in the multiple regression model. To facilitate the selection of variables, a categorization method was used. The logic behind this method is that LBD is a multifactorial disorder. Biomechanical, psychosocial, and individual factors all contribute to the development of LBD. In the NRC review of work-related musculoskeletal disorders (National Research Council and Institute of Medicine, 2001), lifting and carrying loads, frequent bending and twisting, and heavy physical work were all associated with increased risk of LBD. Therefore, the categories (load moment, position/kinematics, and temporal variables) used in the current study best represent the force, posture, and frequency characteristics of the risk factors. Building the model this way will help understand the biological plausibility of the model.

The prospective change in low back functional status (Pn) can be predicted by a multiple logistic regression model with three variables, which represented the three categories of biomechanical risk factors. Absolute maximum resultant dynamic moment is the maximum total moment experienced by the workers during the exertions. It incorporates both the lifting component and the pushing/pulling component of the exertions. Greater pushing/pulling force may increase the spinal shear force. It is not surprising that maximum lateral trunk acceleration entered the model, since this variable has been much higher among all the acceleration variables. Higher lateral acceleration indicates greater asymmetric trunk motion, which could accentuate spine loading due to increased muscle coactivation. Duration is an important duty cycle measure. Longer exertions impose longer loads on the lumbar spine. This does not necessarily mean that when the exertion is shorter the risk of the job is lower. Shorter exertion may cause the body to move faster, hence the velocity and acceleration of the trunk may increase, which could make the job more risky. Therefore, the interactions between the risk factors must be considered when applying the model.

The same variables that predicted the change of Pn did not show the same predictive power for incidence rate (I200k). This is understandable because the data of Pn change were very different from the I200k data. First, the change of Pn was prospectively followed up for 6-14 months, while the I200k data were collected cross-sectionally for the 3 years preceding the workplace assessments. Second, they were measuring different endpoints. Pn measured the functional status of the low back, which can be treated as a disability index. I200k data are based upon injury reporting, which is subject to errors such as missing reports, under-, or over-reporting. However, the model generated for the I200k outcomes still has some commonalities to the model generated for the Pn change.

For example, both included dynamic moment variables. The average horizontal (XY) dynamic lift moment used in the I200K model is a dynamic moment variable, although it only considers the lifting Z force. The Pn model, on the other hand, uses the absolute maximum resultant dynamic moment which, as described above, includes both the lifting and horizontal exertions in determining the resultant force used to compute the moment. Both models have lateral trunk acceleration, although the I200k model uses the integrated measure of acceleration. Duration of non-load exposure in the I200k model is complementary to the duration variable employed in the Pn model. Nonetheless, the I200k model has excellent sensitivity (80%) and specificity (87%).

The three variables selected for both the Pn model and the I200k model have strong biomechanical implications. Using validated 3-dimensional models of spine loading many studies have demonstrated how increases in load moment increases the compression, shear, and torsion forces on the spine (Bean, Chaffin, & Schultz, 1988; Cholewicki & McGill, 1996; Cholewicki, McGill, & Norman, 1991; Davis, Marras, & Waters, 1998; de Looze, Kingma, Thunnissen, van Wijk, & Toussaint, 1994; Granata & Marras, 1995; Granata & Marras, 1999; Hughes & Chaffin, 1997; Marras & Davis, 1998; Marras & Granata, 1995; Marras & Granata, 1997; Marras & Granata, 1997; McGill & Hoodless, 1990; McGill & Norman, 1986; Nussbaum & Chaffin, 1998; Thelen, Schultz, & Ashton-Miller, 1995). Spine loading in excess of the 3400 N tolerance limit, may cause endplate damage, malnutrition of the disc, and eventually disc degeneration or herniation (NIOSH, 1981).

Lateral trunk acceleration could result from task asymmetry and lateral trunk motion. A previous study has shown that spine compression and lateral shear forces increased as the lift origin became more asymmetric (Marras & Davis, 1998). Another study demonstrated that trunk muscle coactivation significantly increased during lateral bending motions (Marras & Granata, 1997). These authors showed that incorporating muscle coactivity into their model increase spinal loads by as much as 25% relative to more simplistic models overlooking muscle co-contraction. Their estimates of spine compression, AP shear, and lateral shear all increased lateral bending velocities increased. Given that spine tolerance to shear forces is much lower than to compression (Yingling & McGill, 1999), lateral trunk motions may impose significant risk of injury on the lumbar spine.

Duration of exertions and the inter-lift periods are closely related to the cumulative nature of LBD. Repetitive loading with shorter recovery time may cause changes in the integrity of the intervertebral disc as well as changes in the ability of the vertebral endplates to nourish the disc (Adams, Green, & Dolan, 1994; Maroudas, Stockwell, Nachemson, & Urban, 1975; Natarajan, Ke, & Andersson, 1994; Yingling & McGill, 1999). The cumulative effects of repetitive muscle activation include muscle fatigue and inflammatory responses (Dolan & Adams, 1998; Nielsen, Andersen, & Jorgensen, 1998; Bonato, Ebenbichler, Roy, Lehr, Posch, Kollmitzer, & Della Croce, 2003; Barr & Barbe, 2004). Longer duration exertions and shorter periods between lifts will increase the cumulative loading on the spine as well as the risk of LBD.

The fifth specific aim to develop a simplified approach that can be used by practitioners to easily evaluate work tasks was accomplished by developing multiple logistic regression models using variables that do not require complicated instrumentation, such as the METS. Average box weight and duration of exertion best predict the change of Pn with reasonable sensitivity and specificity. Both variables are easy to measure with simple tools, such as a spring scale and a stop watch. These two variables belong to the load moment and temporal categories. Since any measurement of trunk position or kinematics needs specialized tools, variables from this category were not included in the model.

The simplified model for I200k used maximum horizontal (XY) static lift moment and duration of non-load exposure. We were not able to find any simpler variable that can be used as a surrogate of the average XY dynamic lift moment. The difficulty of predicting high risk jobs in the I200k data could also be related to the difference between the I200k data and the Pn change data. While duration of non-load exposure can be easily measured with a stop watch, the maximum XY static lift moment may require more effort to collect. First, the box weight can be measured by a spring scale. The difference between a spring scale and the load cells in the handles of METS is less than one pound. Second, one must measure the horizontal distance from the box to the lumbar spine to get the moment arm. Using a tape measure, an experienced data collector can have an error of 4.3 inches. Hence, there might be a 3-inch difference between the hand measure and the METS determined moment arm. Caution must be taken to reduce the error associated with moment arm measurement. Third, typically the maximum moment arm occurs at the beginning or the end of an exertion. Thus, the moment arm should be collected at least twice during an exertion with the maximum value going into the static moment calculation.

There are several limitations in this project. First, METS was designed to use the pin grippers on the handles to pick up loads. Certain types of loads, such as bottles of water, bulky items, and furniture cannot be held with the pin grippers. As these tend to be heavier items, this may underestimate the physical exposure of the job. In some distribution centers, loads were carried in plastic totes. Special catches were designed for the METS and used to handle the totes. The lifting style of the workers may have slightly changed by wearing METS, which has some constraints on the person. Although our models were based on using this type of equipment, we still have faith in the validity of the valuable information we collected. Second, only distribution center jobs were sampled in this study. The results of the study only apply to the distribution industry. Third, the follow-up rate of the study is relatively low. This was partly because of the high turnover rate in distribution center workers. Low follow-up rate reduced the number of subjects remained on some jobs. When the number of subjects at follow-up was less than 2, the job was not included in the analysis. Fourth, because jobs are the unit of analysis, the sample size (50 jobs) limited the number of variables that can enter the multiple logistic regression models. Finally further studies are needed to validate the models developed in this study.

5. Conclusions

1. The dynamic load moment, trunk kinematics, and duty cycle variables are all important risk factors for work-related low back disorders.
2. Using a specialized instrumentation allows us to accurately quantify the physical exposure of manual materials handling jobs in distribution centers.
3. Manual materials handling jobs in the distribution industry have a very high physical exposure level which involves considerable dynamic trunk motions.
4. The combinations of dynamic moment, lateral trunk acceleration, and temporal variables are predictive of the change of low back functional status (P_n) and low back injury rate (I_{200k}).
5. Simplified regression models can be used in industry to identify high risk jobs for low back injury with reasonable sensitivity and specificity.

Publications

1. Lavender SA, Marras WS, Ferguson SA, Splittstoesser RE, Yang G, Schabo P. Quantifying load moment exposure in distribution center work. Sixth International Scientific Conference on Prevention of Work-Related Musculoskeletal Disorders (PREMUS). Aug 27-30, 2007; Boston, MA, USA.
2. Ferguson SA, Marras WS, Lavender SA, Splittstoesser RE, Yang G, Schabo P. Differences between lifting and lowering manual material handling tasks in distribution centers. Proceedings of the Human Factors and Ergonomics Society 51st Annual Meeting. Oct 1-5, 2007; Baltimore, MD, USA.

We are planning to submit a series of journal articles to publish the results of this project.

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Inclusion of gender and minority study subjects

Principal Investigator/Program Director (Last, First, Middle):

Marras, William, S.

Inclusion Enrollment Report

This report format should NOT be used for data collection from study participants.

Study Title: Identifying Safe Load Moment Exposures for the Back

Total Enrollment: 888

Protocol Number: 2003H0188

Grant Number: U01 OH007313

PART A. TOTAL ENROLLMENT REPORT: Number of Subjects Enrolled to Date (Cumulative) by Ethnicity and Race				
Ethnic Category	Sex/Gender			Total
	Females	Males	Unknown or Not Reported	
Hispanic or Latino	5	38	0	43 **
Not Hispanic or Latino	130	711	0	841
Unknown (individuals not reporting ethnicity)	0	4	0	4
Ethnic Category: Total of All Subjects*	135	753	0	888 *
Racial Categories				
American Indian/Alaska Native	2	2	0	4
Asian	1	3	0	4
Native Hawaiian or Other Pacific Islander	1	2	0	3
Black or African American	16	164	0	180
White	111	548	0	659
More Than One Race	0	2	0	2
Unknown or Not Reported	4	32	0	36
Racial Categories: Total of All Subjects*	135	753	0	888 *
PART B. HISPANIC ENROLLMENT REPORT: Number of Hispanics or Latinos Enrolled to Date (Cumulative)				
Racial Categories	Females	Males	Unknown or Not Reported	Total
American Indian or Alaska Native	0	0	0	0
Asian	0	0	0	0
Native Hawaiian or Other Pacific Islander	0	0	0	0
Black or African American	0	0	0	0
White	0	0	0	0
More Than One Race	0	0	0	0
Unknown or Not Reported	5	38	0	43
Racial Categories: Total of Hispanics or Latinos**	5	38	0	43 **

* These totals must agree.

** These totals must agree.

Materials available for other investigators

The final report of this project can be shared with other investigators. Interested researchers may contact us. We have also shared the Moment Exposure Tracking System with University of Wisconsin – Milwaukee as part of the NIOSH consortium.

APPENDICES

APPENDIX A-1

Symptom and psychosocial assessment survey

Symptom and psychosocial assessment survey

Name	_____
Gender	☐ Male ☐ Female
Age	_____
Weight	_____
Height	_____

1. Are you of Hispanic or Latino origin?

- ☐ No
- ☐ Yes

2. Race

- ☐ White
- ☐ Black or African American
- ☐ Asian
- ☐ Native Hawaiian or Pacific Islander
- ☐ Native American or Alaskan Native

3. Have you ever smoked at least 100 cigarettes in your ENTIRE LIFE?

- ☐ No
- ☐ Yes

- 
- ☐ Yes, but I NO LONGER smoke
 - ☐ Yes, I CURRENTLY smoke

4. How long have you worked at this company?

- ☐ Less than 3 months
- ☐ 3 months to less than 1 year
- ☐ 1 year to less than 3 years
- ☐ 3 years to less than 5 years
- ☐ 5 years to less than 10 years
- ☐ 10 years or more

5. How long have you worked in your current job?

- ☐ Less than 3 months
- ☐ 3 months to less than 1 year
- ☐ 1 year to less than 3 years
- ☐ 3 years to less than 5 years
- ☐ 5 years to less than 10 years
- ☐ 10 years or more

6. How long have you been doing this kind of work?

- ☐ Less than 3 months
- ☐ 3 months to less than 1 year
- ☐ 1 year to less than 3 years
- ☐ 3 years to less than 5 years
- ☐ 5 years to less than 10 years
- ☐ 10 years or more

7. Hours per week worked?

- ☐ 20-39 hrs.
- ☐ 40 hrs.
- ☐ 41-60 hrs.
- ☐ over 60 hrs.

8. Have you ever had back pain that has limited your activities?

- ☐ No
- ☐ Yes

9. Have you had back pain more than once in the last 12 months that has limited your activities?

- ☐ No
- ☐ Yes

10. Have you EVER had LOW BACK pain every day for a week (7 days) or more?

- ☐ No
- ☐ Yes

11. In the past 12 months, have you had BACK pain every day for a week (7 days) or more?

- ☐ No
- ☐ Yes

12. In the past 12 months, how many times have you SEEN a doctor, nurse, physical therapist or chiropractor or other health care provider for your BACK symptoms?

- ☐ None in the past 12 months
- ☐ 1 time
- ☐ 2 to 5 times
- ☐ More than 5 times

13. How many days have you MISSED WORK in the past 12 months because of BACK symptoms?

- ☐ 0 days
- ☐ 1 day to 1 week
- ☐ More than 1 week to 2 weeks
- ☐ More than 2 weeks

14. Did the back pain you had in the past 12 months result from an accident such as slipping or falling?

- ☐ No
- ☐ Yes

15. Have you experience knee pain in past 12 months that restricted your activities?

- ☐ No
- ☐ Yes

16. Did the knee pain you had in the past 12 months result from an accident such as slipping or falling?

- ☐ No
- ☐ Yes

17. Have you experienced knee pain more than once in the past 12 months that restricted your activities?

- ☐ No
- ☐ Yes

18. In the past 12 months have you experience shoulder pain that restricts your activities?

- ☐ No
- ☐ Yes

19. Have you experienced shoulder pain that restricts your activities more than once in the past 12 months?

- ☐ No
- ☐ Yes

20. Please indicate how little or how much INFLUENCE or CONTROL you have over aspects of your work:

The variety of tasks you perform?

- ☐ Very little
- ☐ A little
- ☐ Moderate amounts
- ☐ Much
- ☐ Very much

The order in which you perform tasks at work?

- ☐ Very little
- ☐ A little
- ☐ Moderate amounts
- ☐ Much
- ☐ Very much

The pace of your work, that is how fast or slow you work?

- ☐ Very little
- ☐ A little
- ☐ Moderate amounts
- ☐ Much
- ☐ Very much

The extent to which you can work ahead and take a short break during work hours?

- ☐ Very little
- ☐ A little
- ☐ Moderate amounts
- ☐ Much
- ☐ Very much

21. Please indicate how much or how little support you receive on the job.

How much does your immediate supervisor (boss) go out of his/her way to make your work life easier for you?

- ☐ Very much (or very easy)
- ☐ Much (easy)
- ☐ A little
- ☐ Not at all

How much can your immediate supervisor (boss) be relied upon when things get tough at work?

- ☐ Very much (or very easy)
- ☐ Much (easy)
- ☐ A little
- ☐ Not at all

How easy is it to talk with your immediate supervisor (boss)?

- ☐ Very much (or very easy)
- ☐ Much (easy)
- ☐ A little
- ☐ Not at all

How much do your co-workers go out of their way to make your work life easier for you?

- ☐ Very much (or very easy)
- ☐ Much (easy)
- ☐ A little
- ☐ Not at all

How much can your co-workers be relied upon when things get tough at work?

- ☐ Very much (or very easy)
- ☐ Much (easy)
- ☐ A little
- ☐ Not at all

How easy is it to talk with your co-workers?

- ☐ Very much (or very easy)
- ☐ Much (easy)
- ☐ A little
- ☐ Not at all

22. All in all, how satisfied are you with your job?

- ☐ Not at all satisfied
- ☐ Not too satisfied
- ☐ Somewhat satisfied
- ☐ Very satisfied

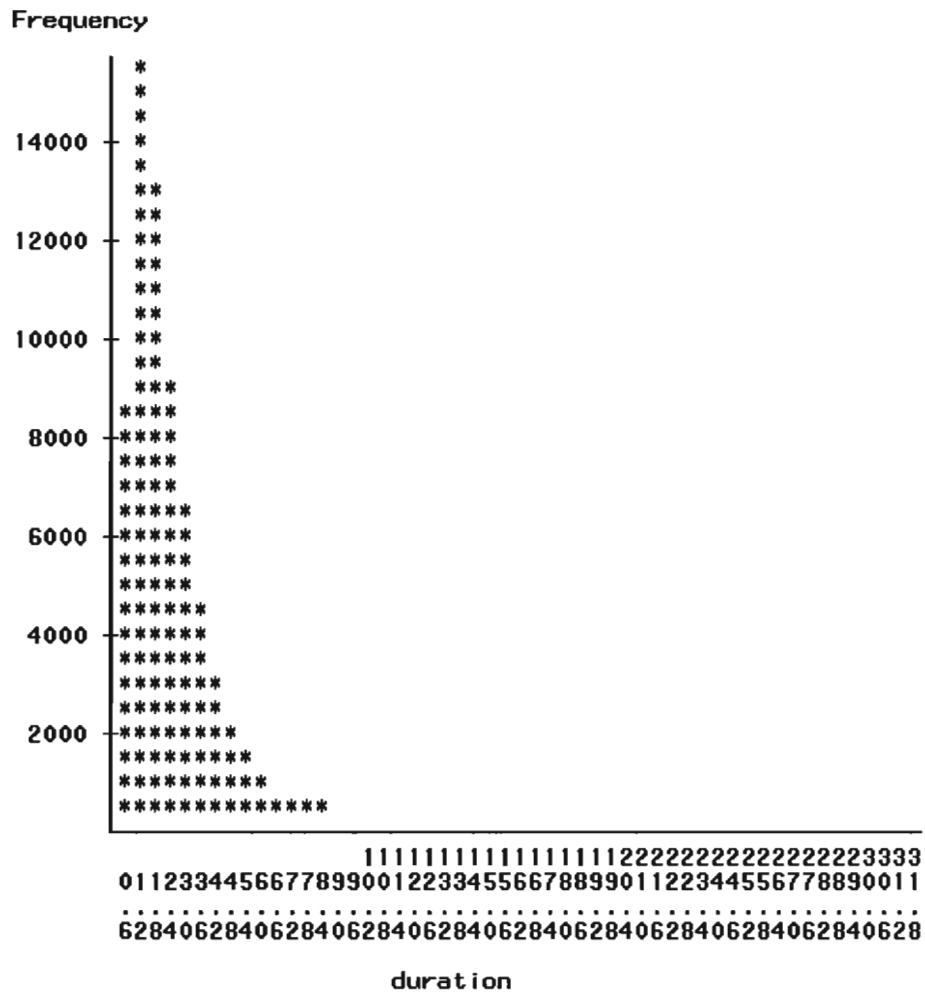
23. Please rate the OVERALL PHYSICAL EFFORT level demanded by your job today.

- ☐ 0 Nothing at all
- ☐ 0.5 Extremely weak (just noticeable)
- ☐ 1 Very weak
- ☐ 2 Weak (light)
- ☐ 3 Moderate
- ☐ 4
- ☐ 5 Strong
- ☐ 6
- ☐ 7 Very strong
- ☐ 8
- ☐ 9
- ☐ 10 Extremely strong (almost max)
- ☐ Maximal

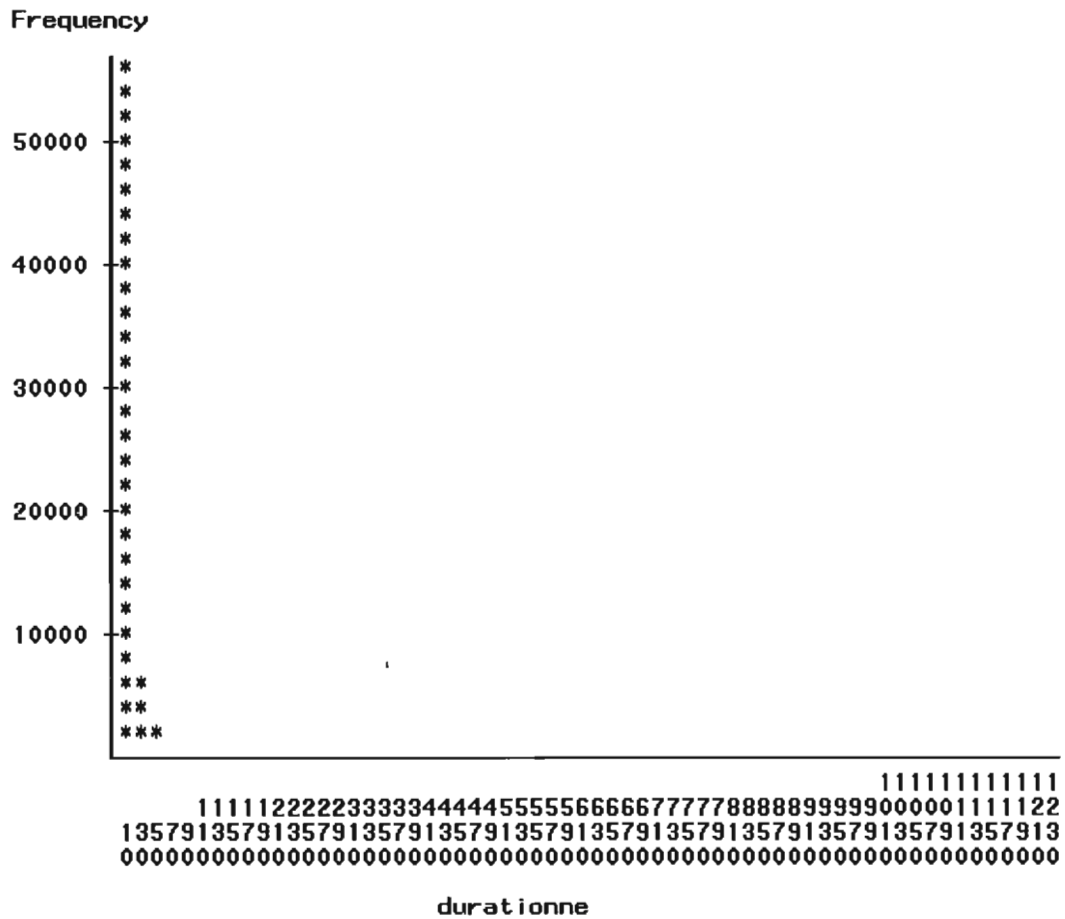
APPENDIX A-2

Distribution Plots of Load Moment Exposure Variables

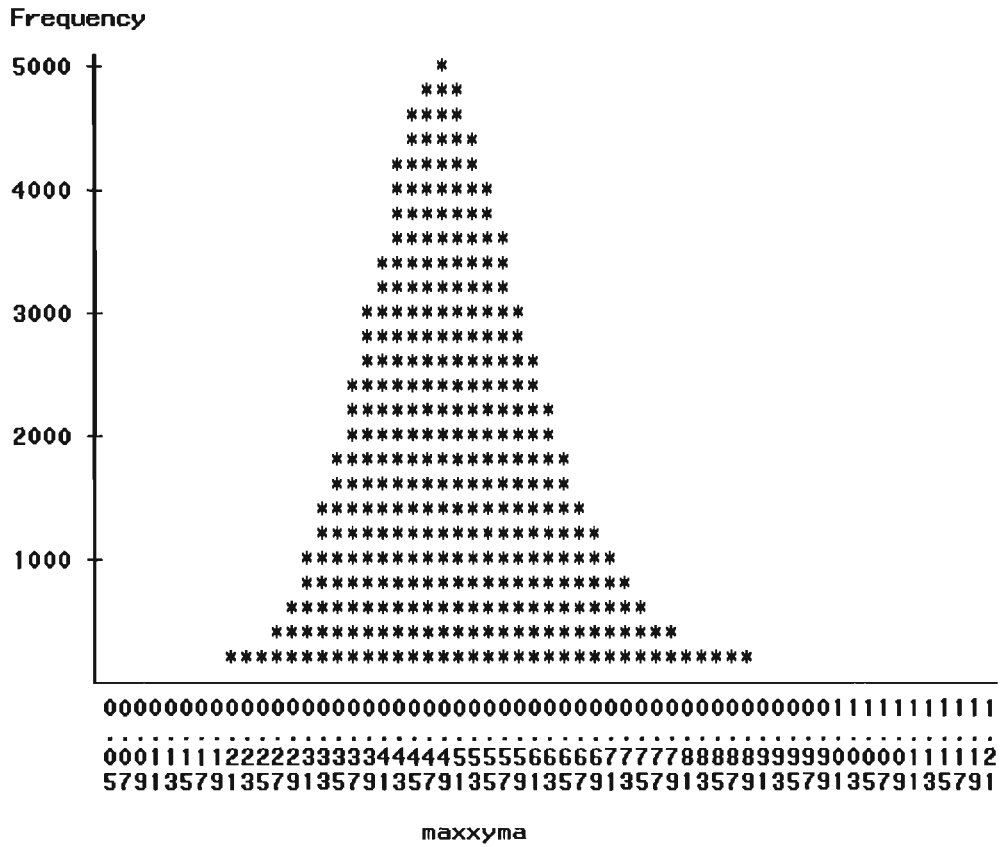
Variable Full Name: Duration (seconds)
Abbreviated Name: duration



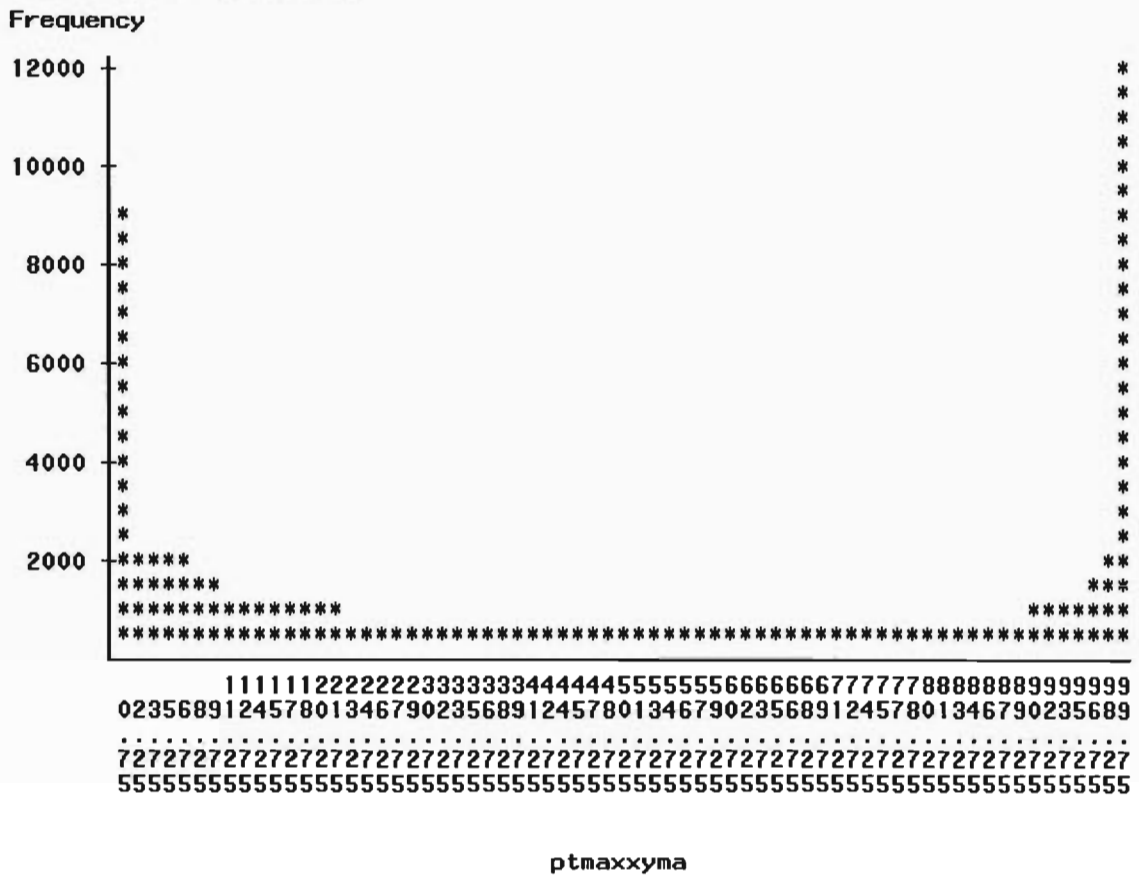
Variable Full Name: Duration of non-load exposure (seconds)
Abbreviated Name: durationne



Abbreviated Name: maxxyma



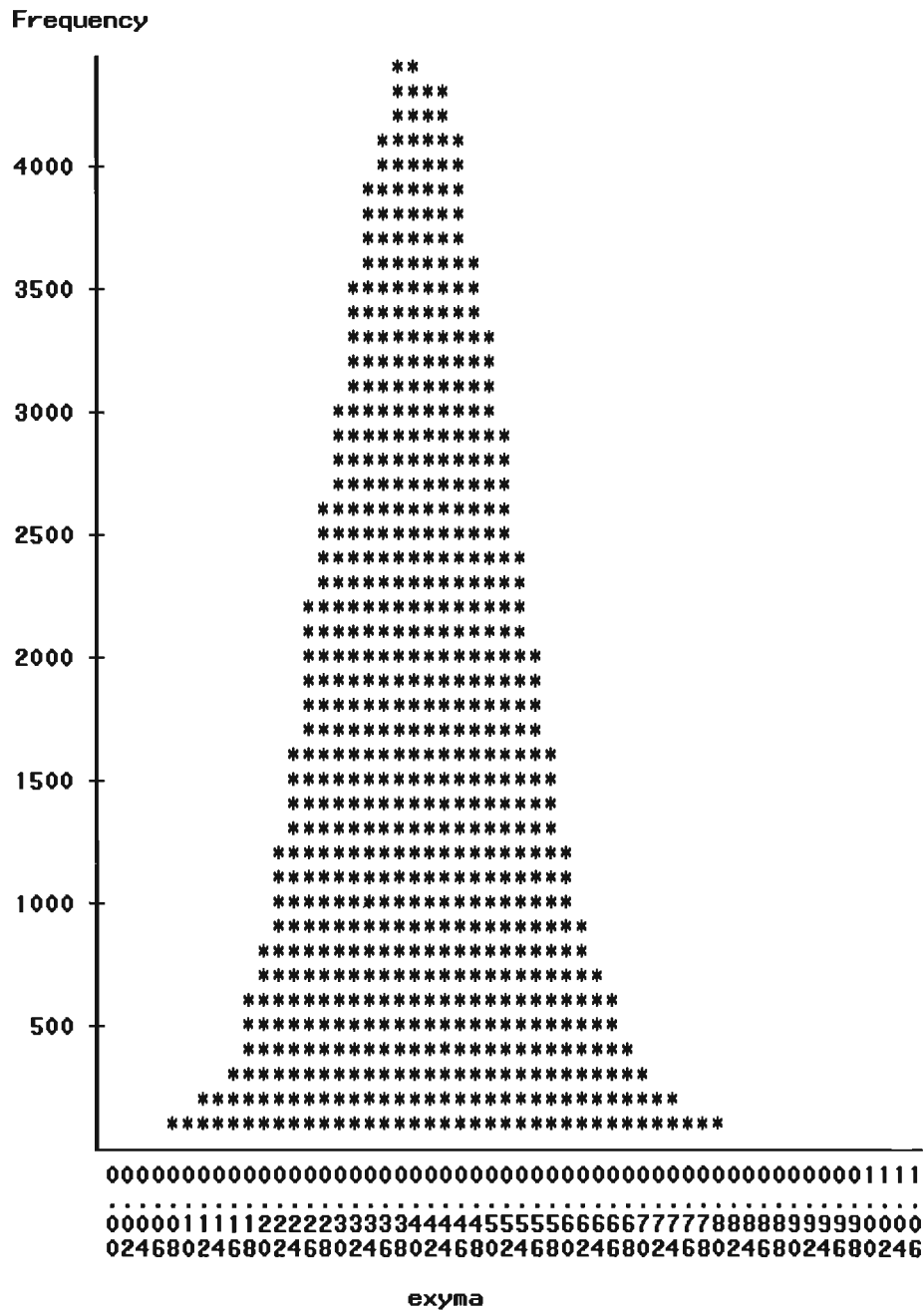
Variable Full Name: Percent Time of Maximum XY Moment Arm (%)
Abbreviated Name: ptmaxxyma



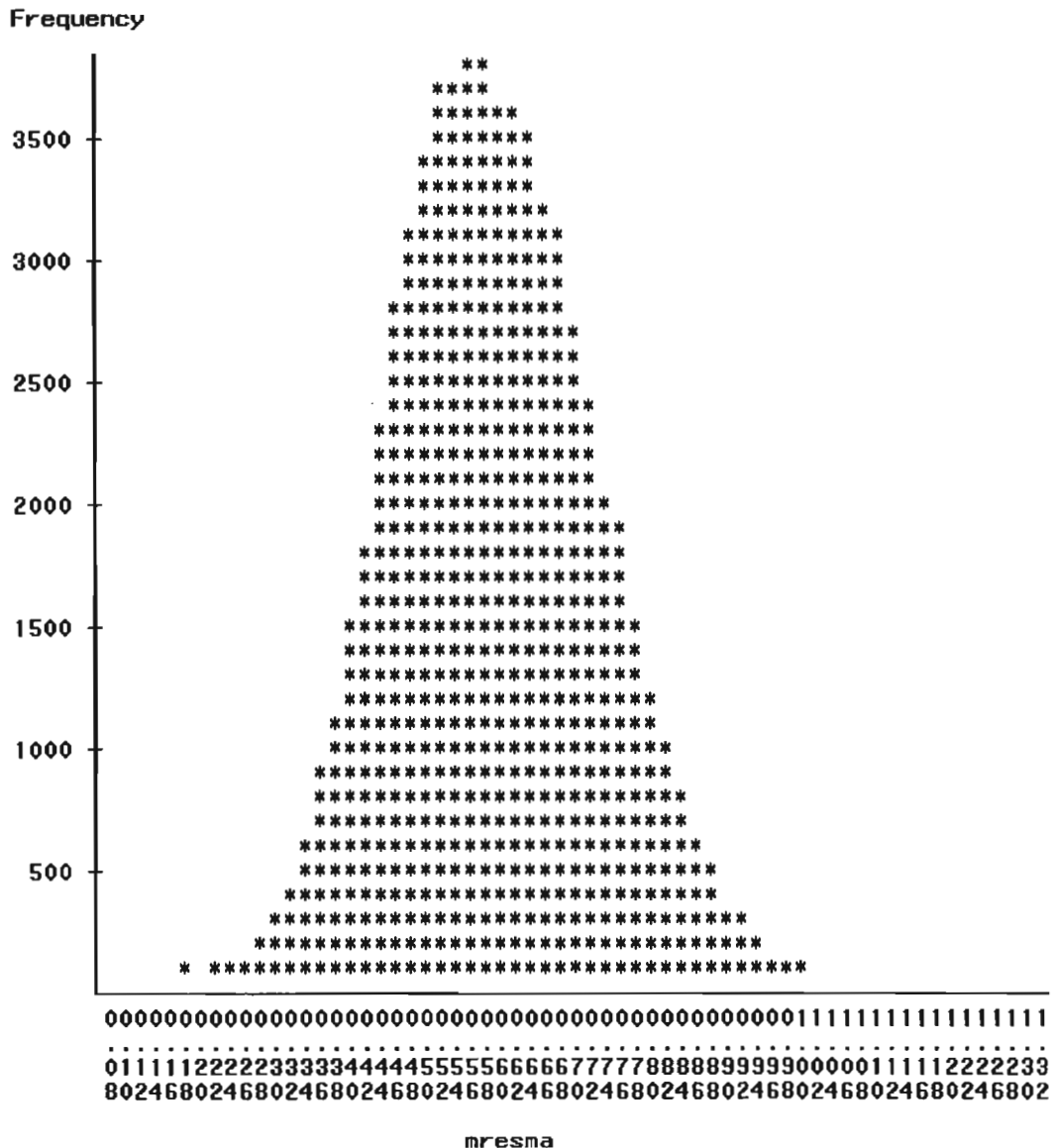
Abbreviated Name: **sxyrna**



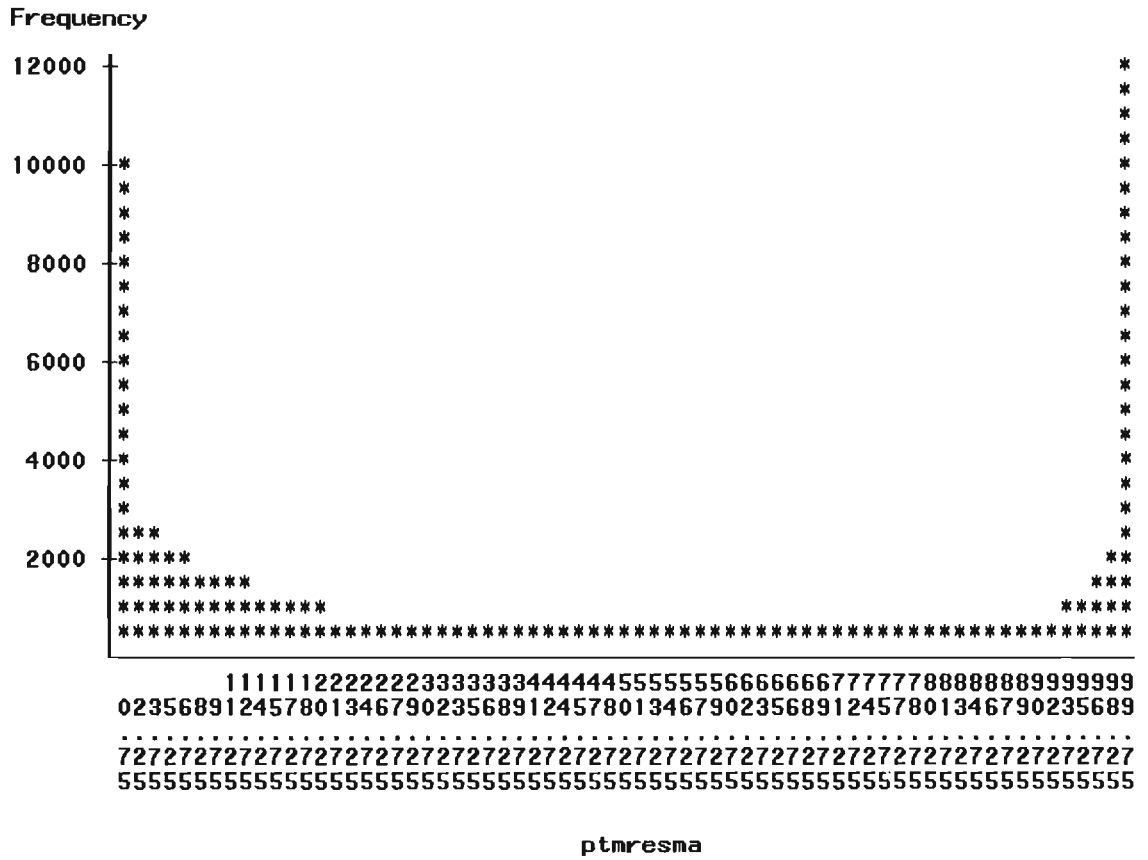
Abbreviated Name: **exyma**



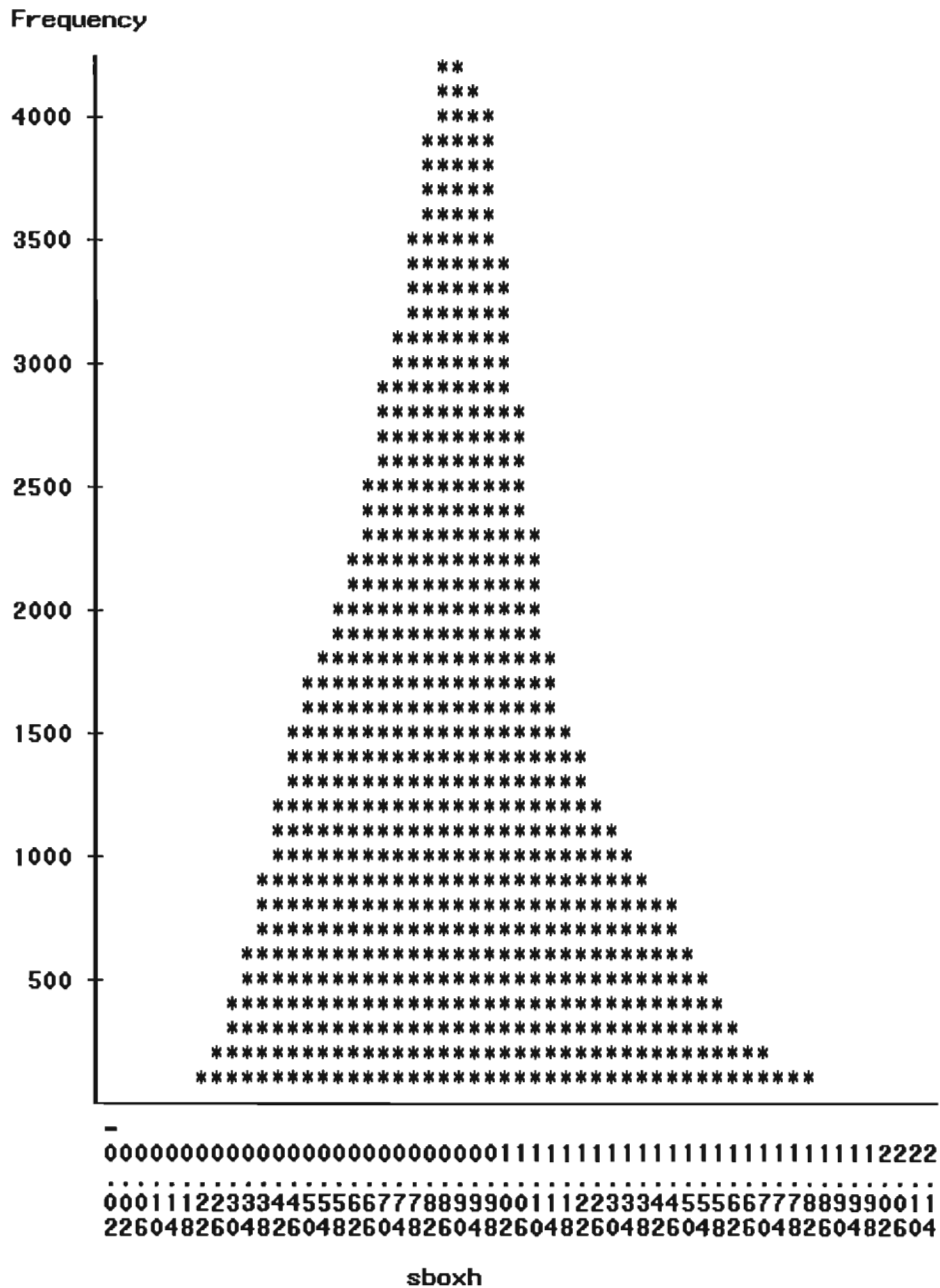
Variable Full Name: Maximum Resultant Moment Arm (m)
Abbreviated Name: mresma



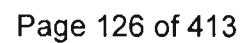
Variable Full Name: Percent Time of Maximum Resultant Moment Arm (%)
 Abbreviated Name: ptmresma



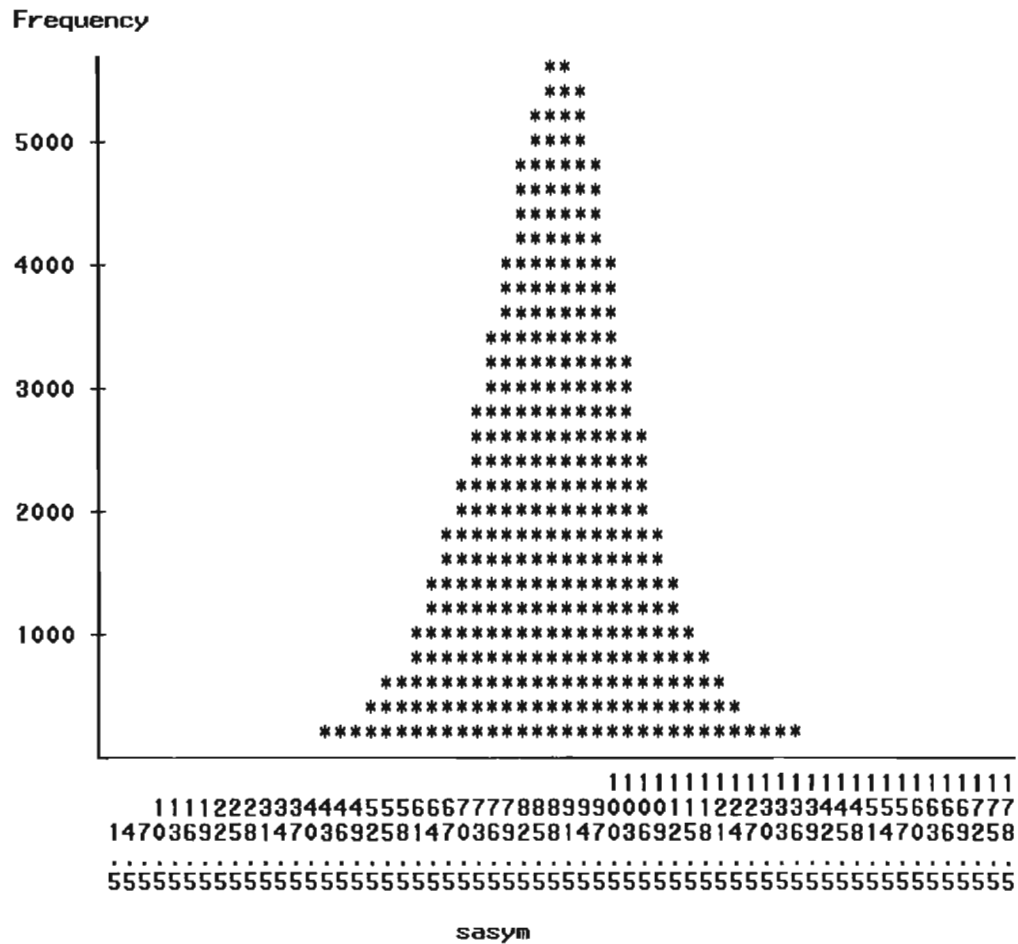
Abbreviated Name: `sboxh`



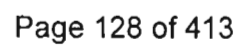
Abbreviated Name: eboxh



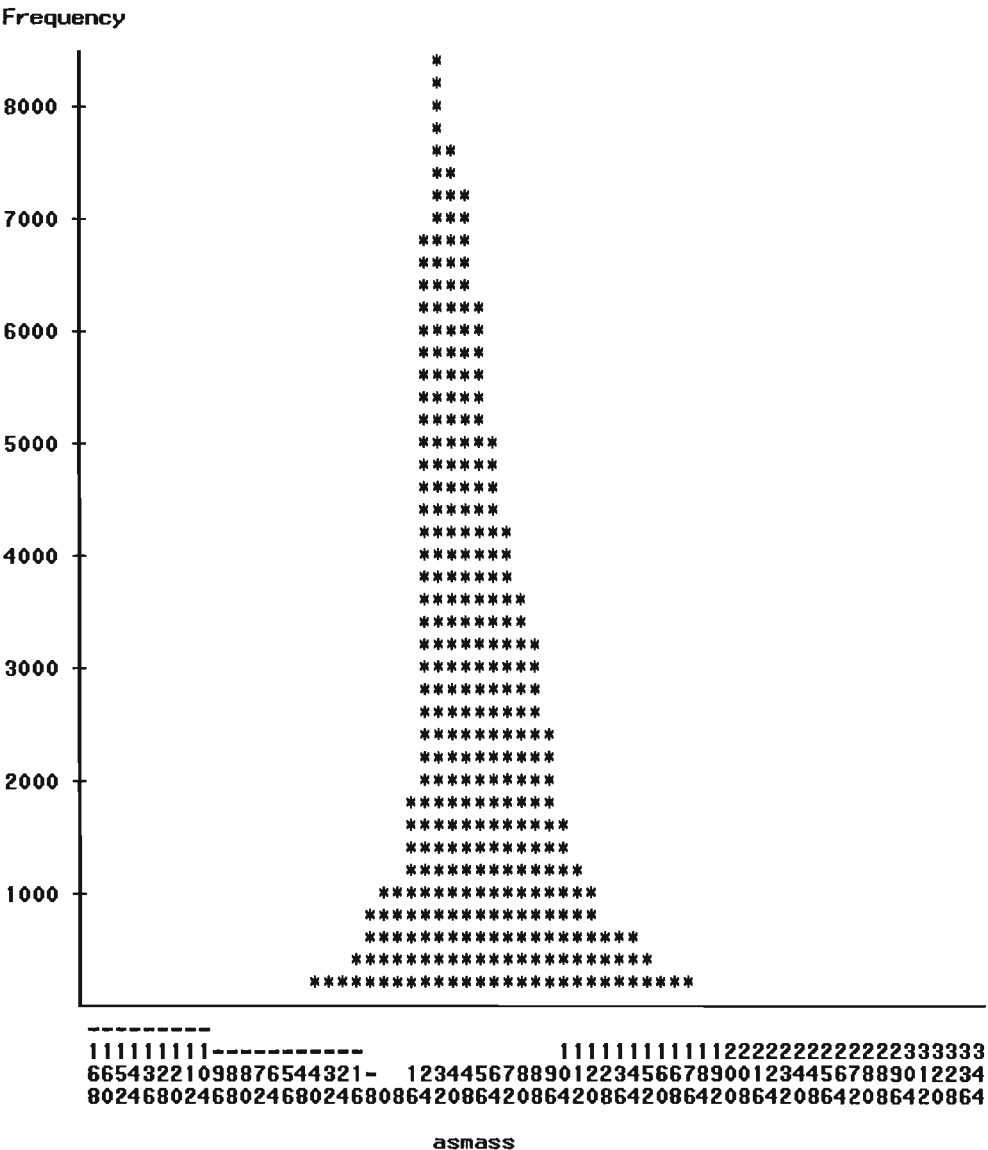
Variable Full Name: Start Asymmetry (Degrees)
Abbreviated Name: sasym



Abbreviated Name: easym

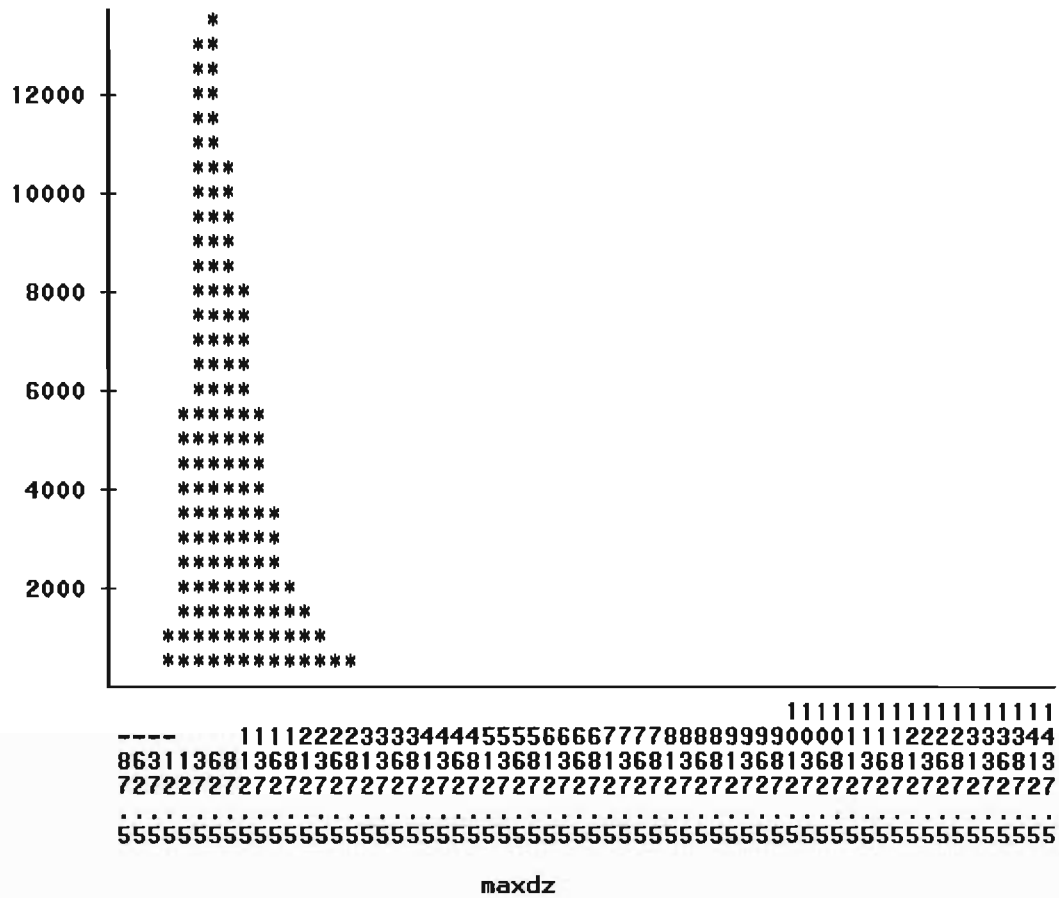


Variable Full Name: Box Weight (N)
Abbreviated Name: asmass

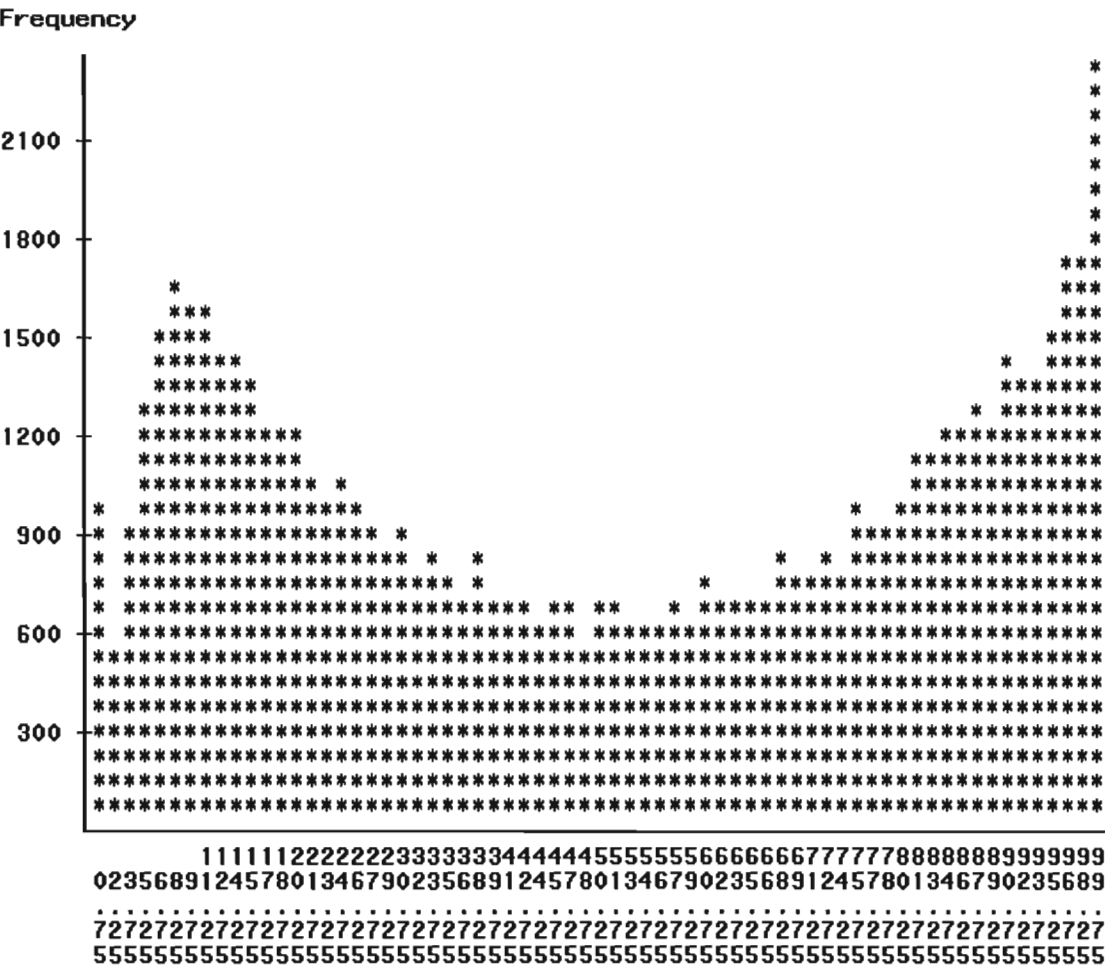


Abbreviated Name: maxdz

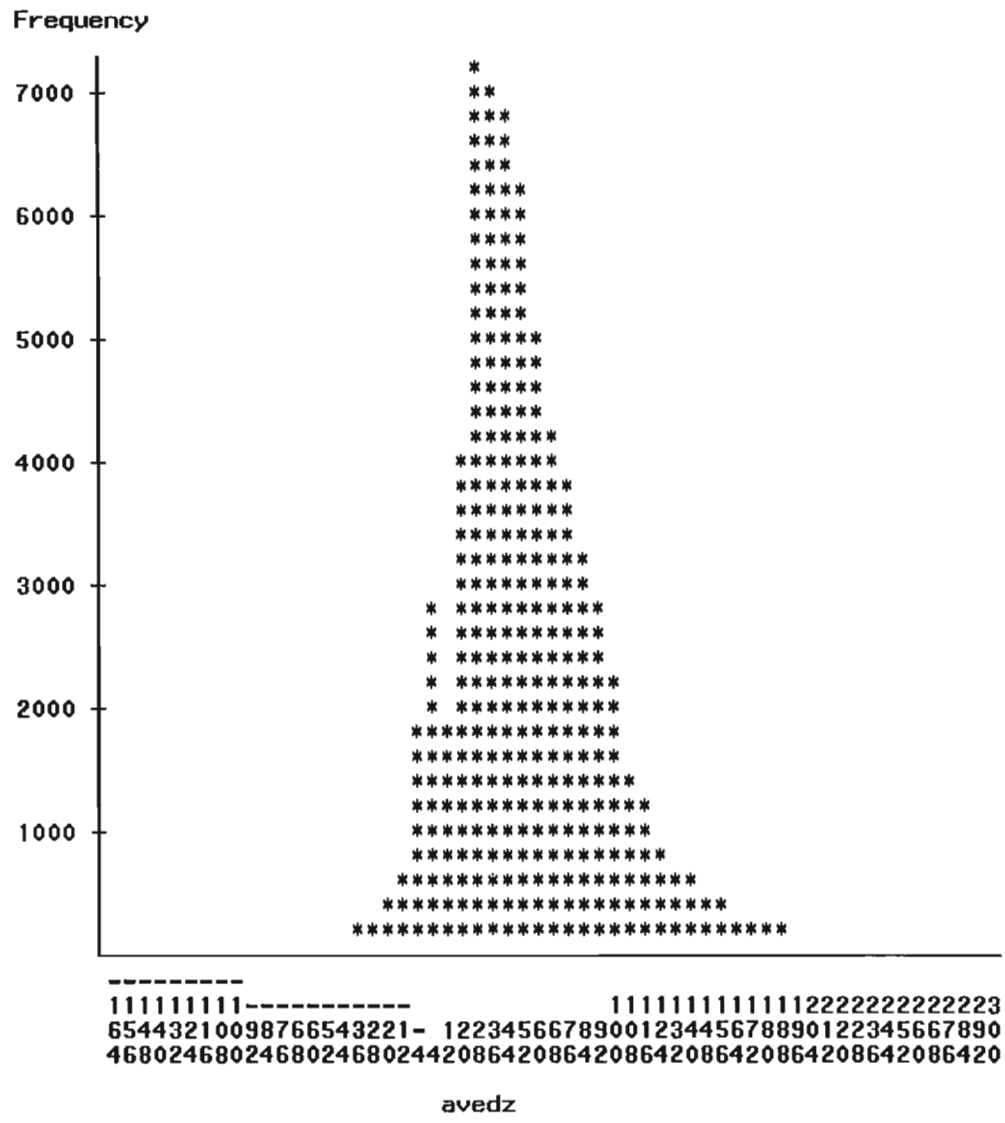
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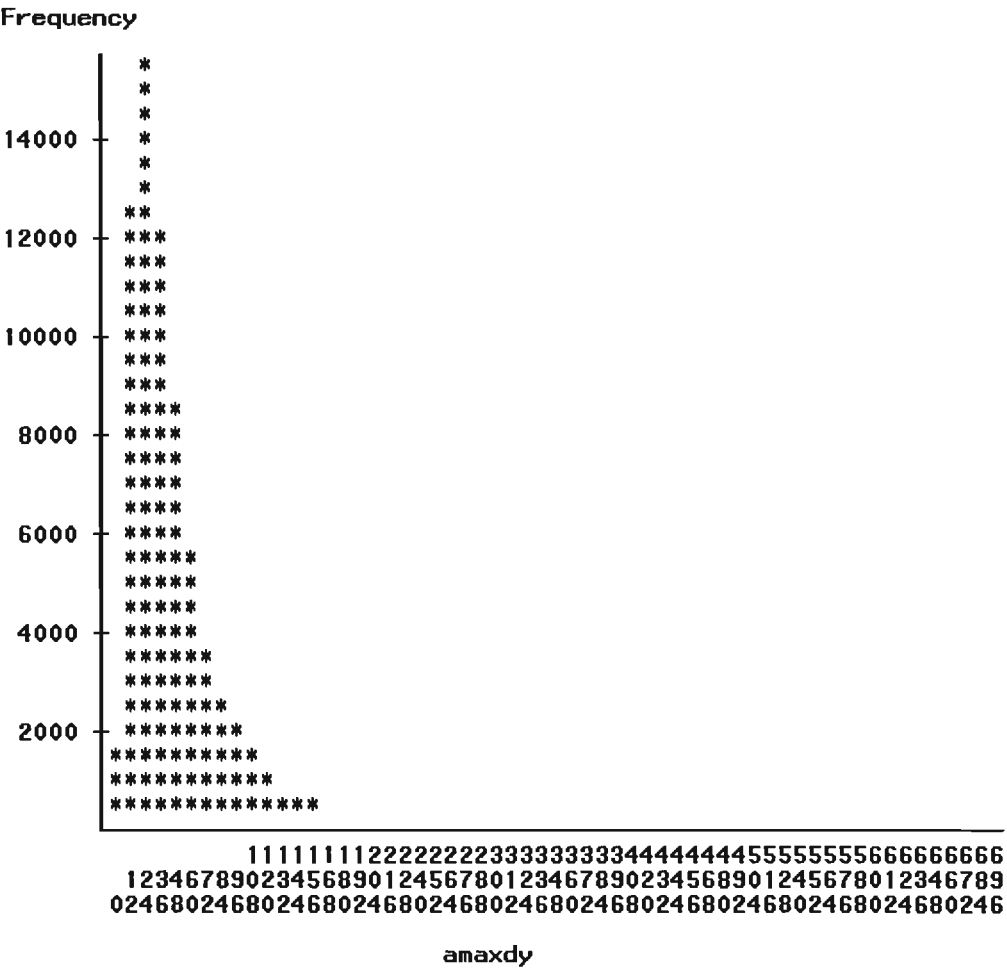
Variable Full Name: Percent Time of Maximum Dynamic Z Force (%)
Abbreviated Name: ptmaxdz



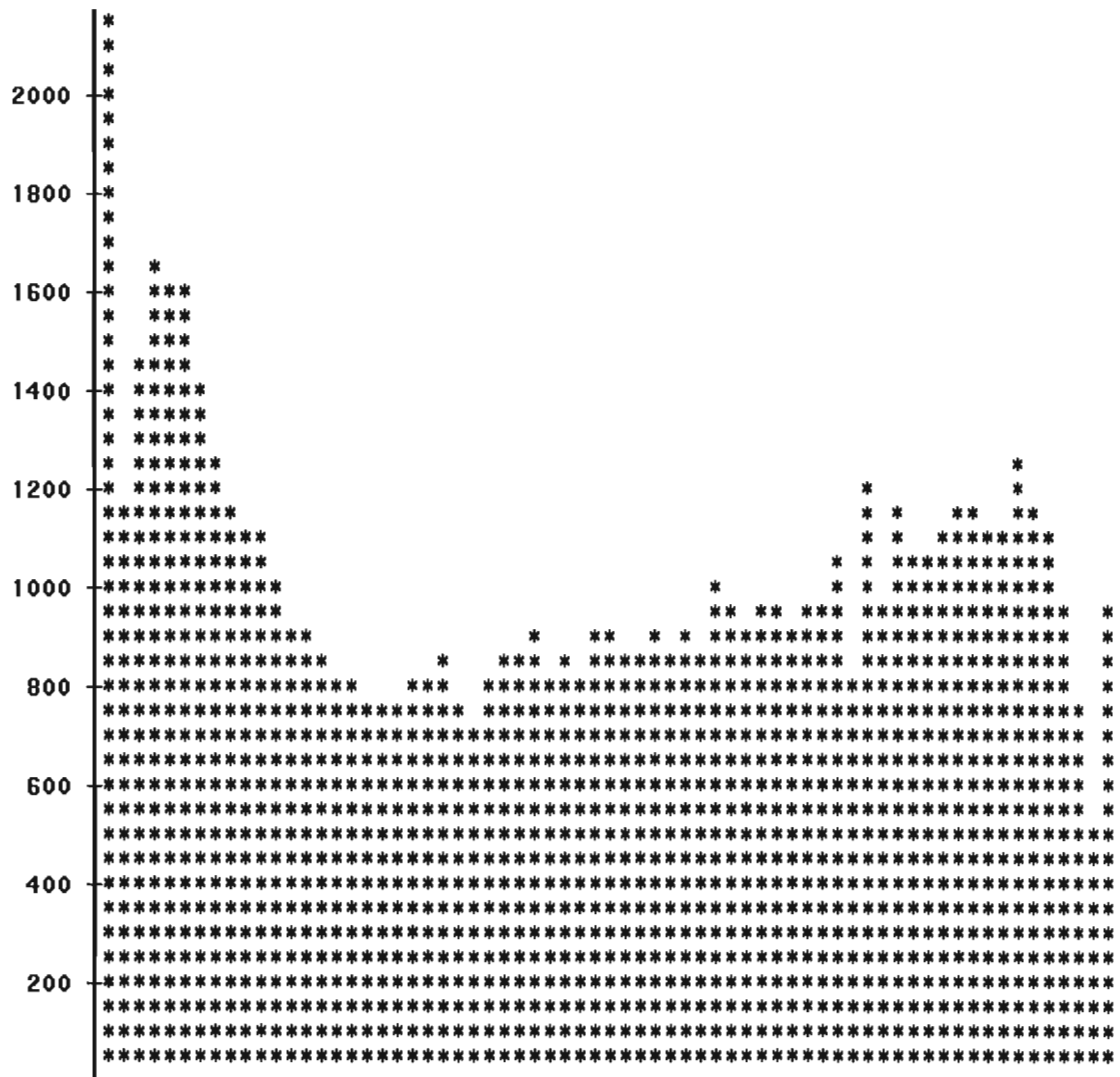
Variable Full Name: Average Dynamic Z Force (N)
Abbreviated Name: avedz



Variable Full Name: Absolute Maximum Dynamic Y Force (N)
Abbreviated Name: amaxdy



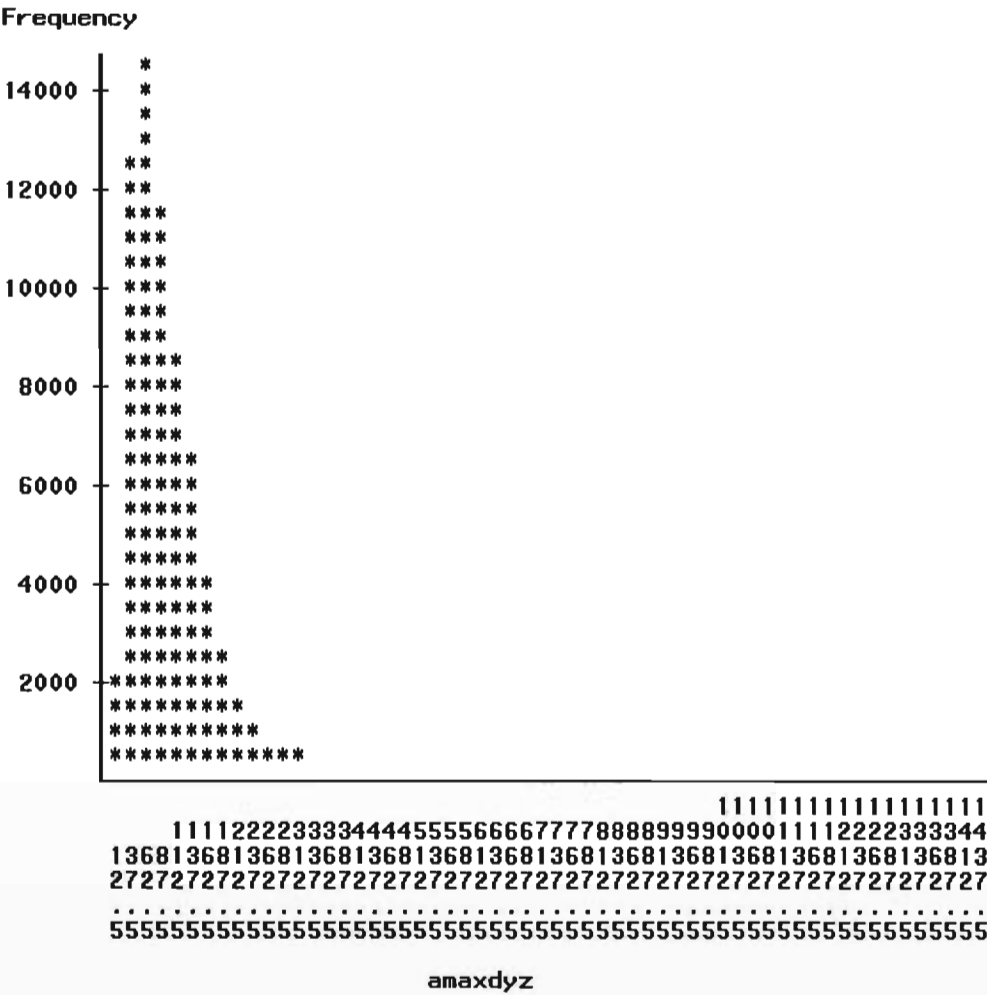
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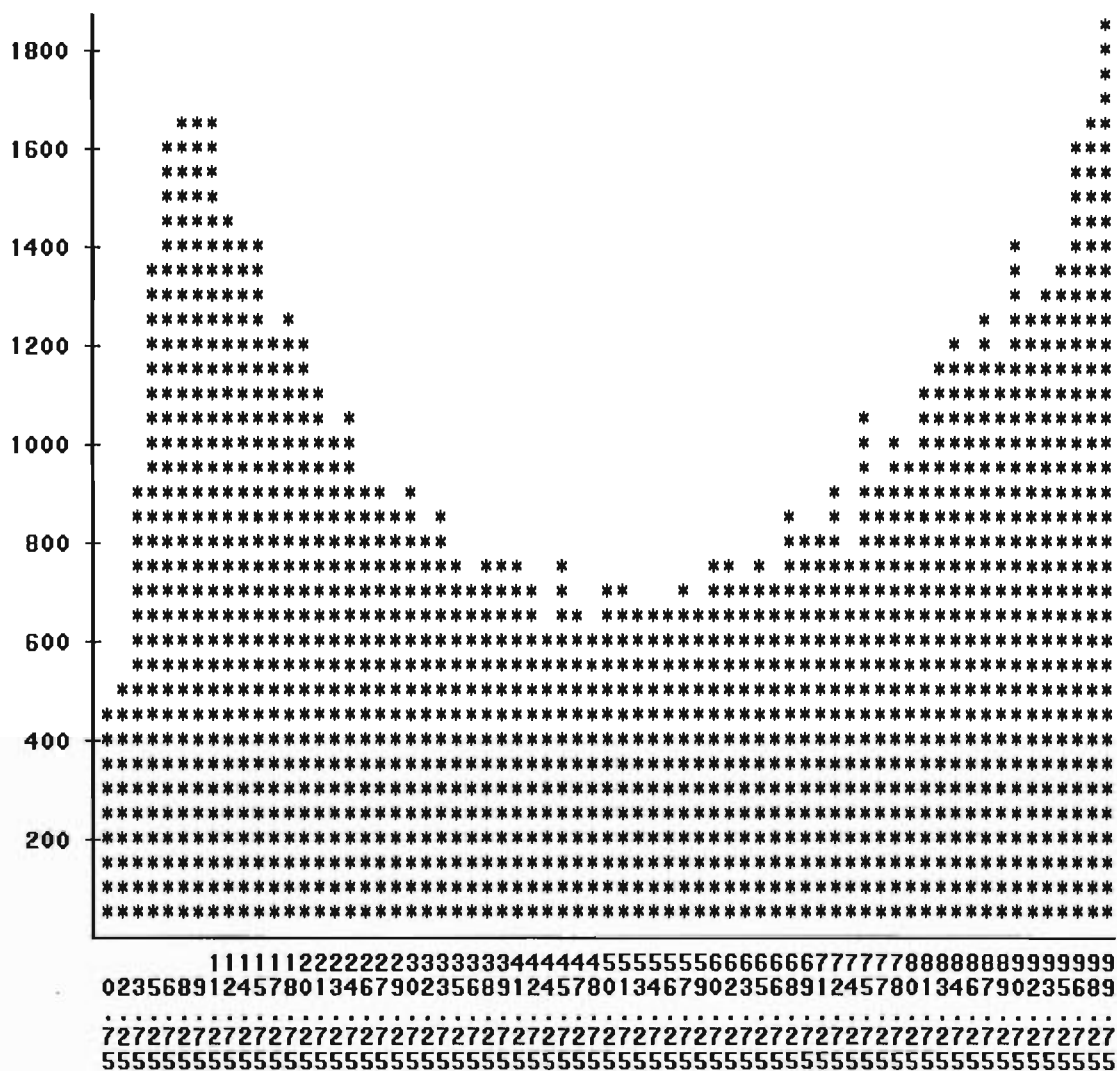
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ptamaxy

Variable Full Name: Absolute Maximum Dynamic YZ Force (N)
Abbreviated Name: amaxdyz

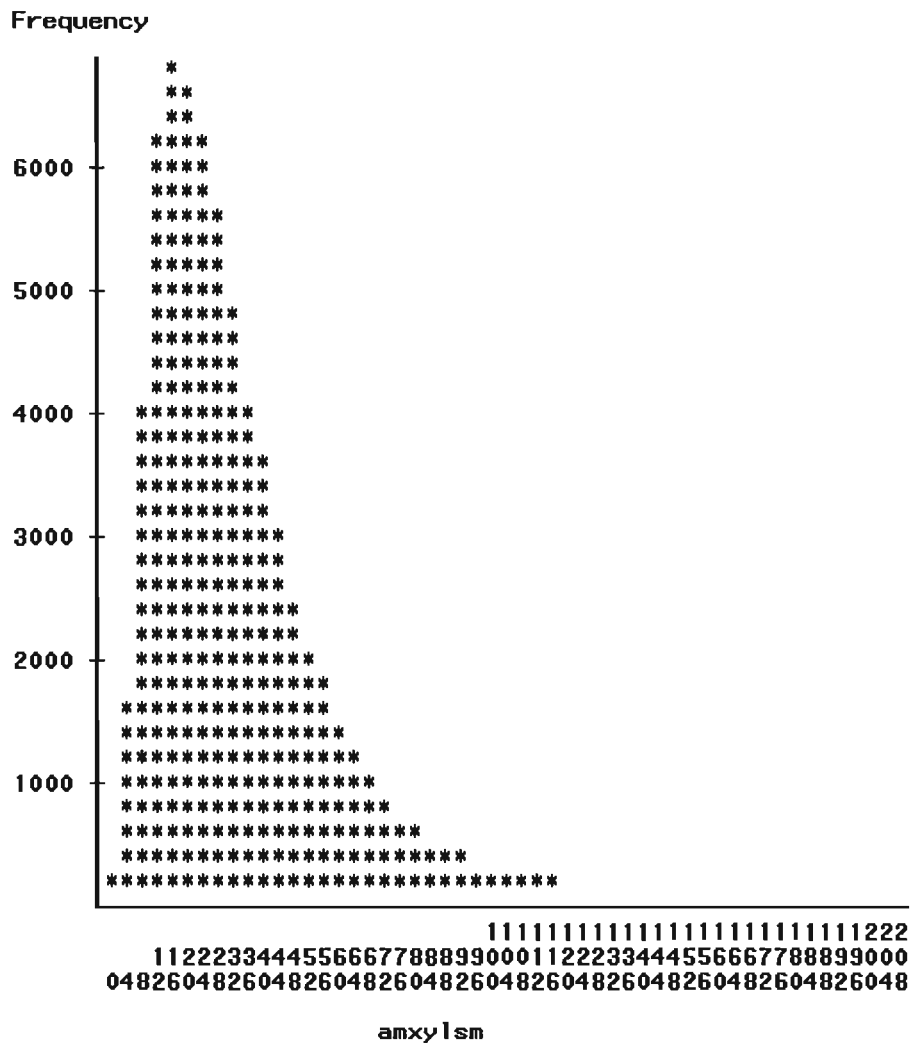


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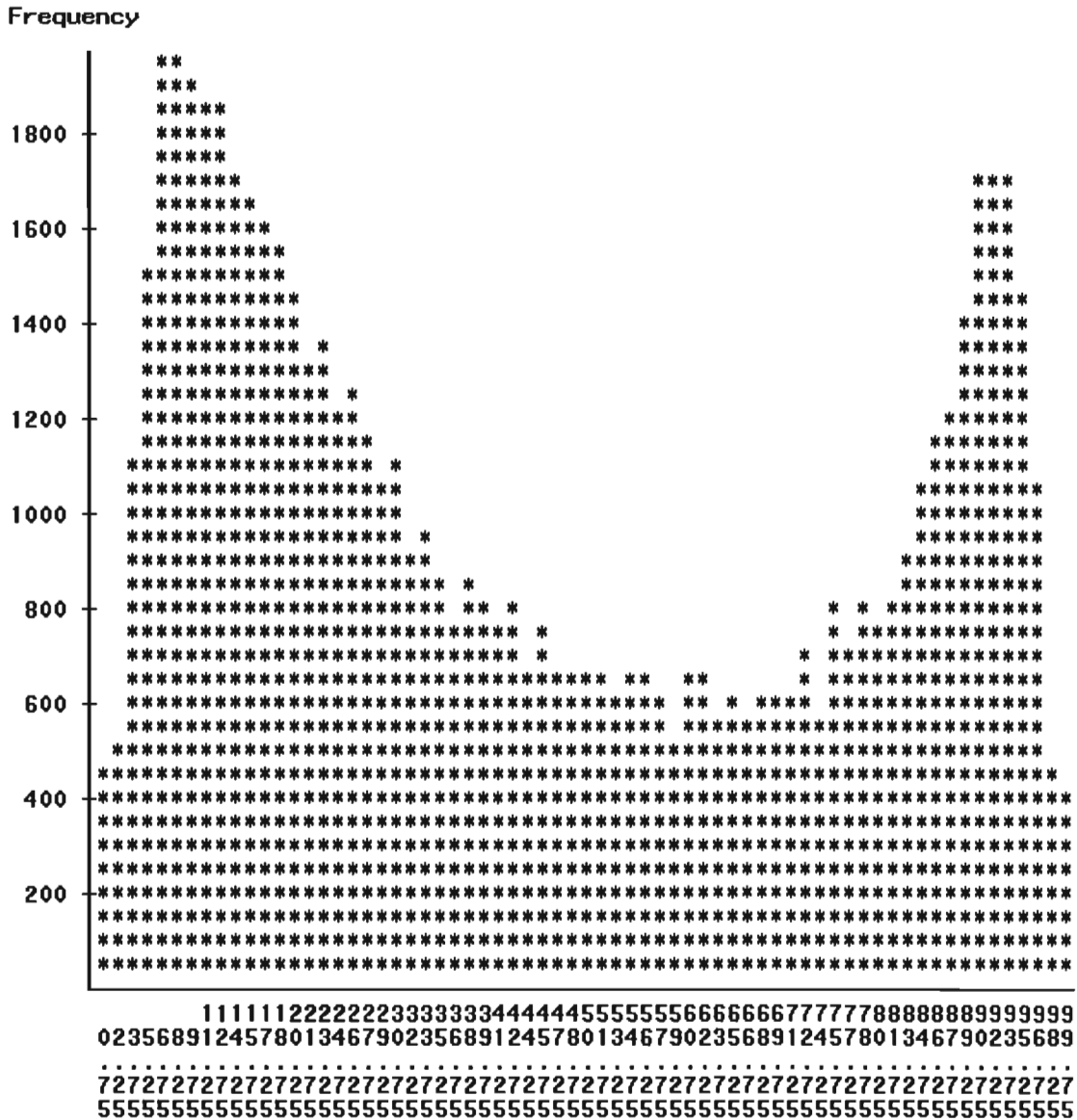


ptamaxdyz

Variable Full Name: Absolute Maximum XY*Lift Static Moment (N*m)
Abbreviated Name: amxylsm

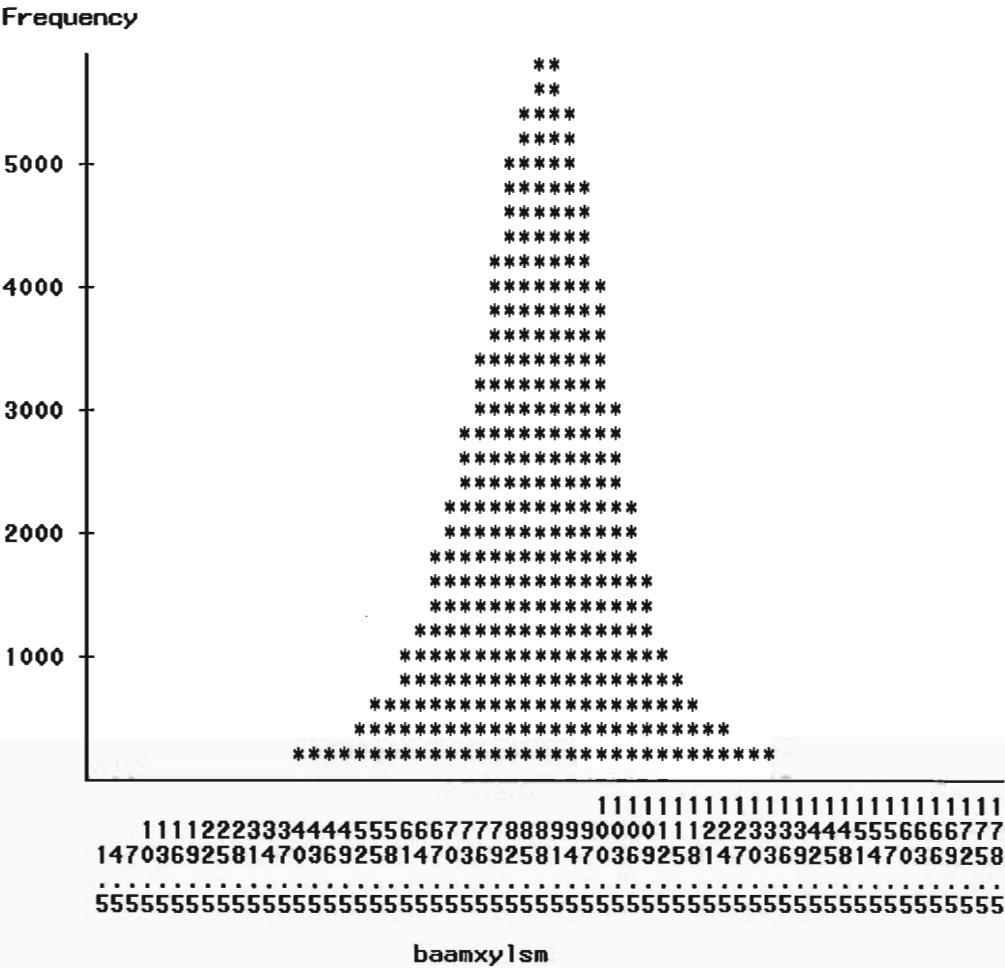


Variable Full Name: Percent Time of Absolute Maximum XY*Lift Static Moment (%)
Abbreviated Name: ptamxylsm

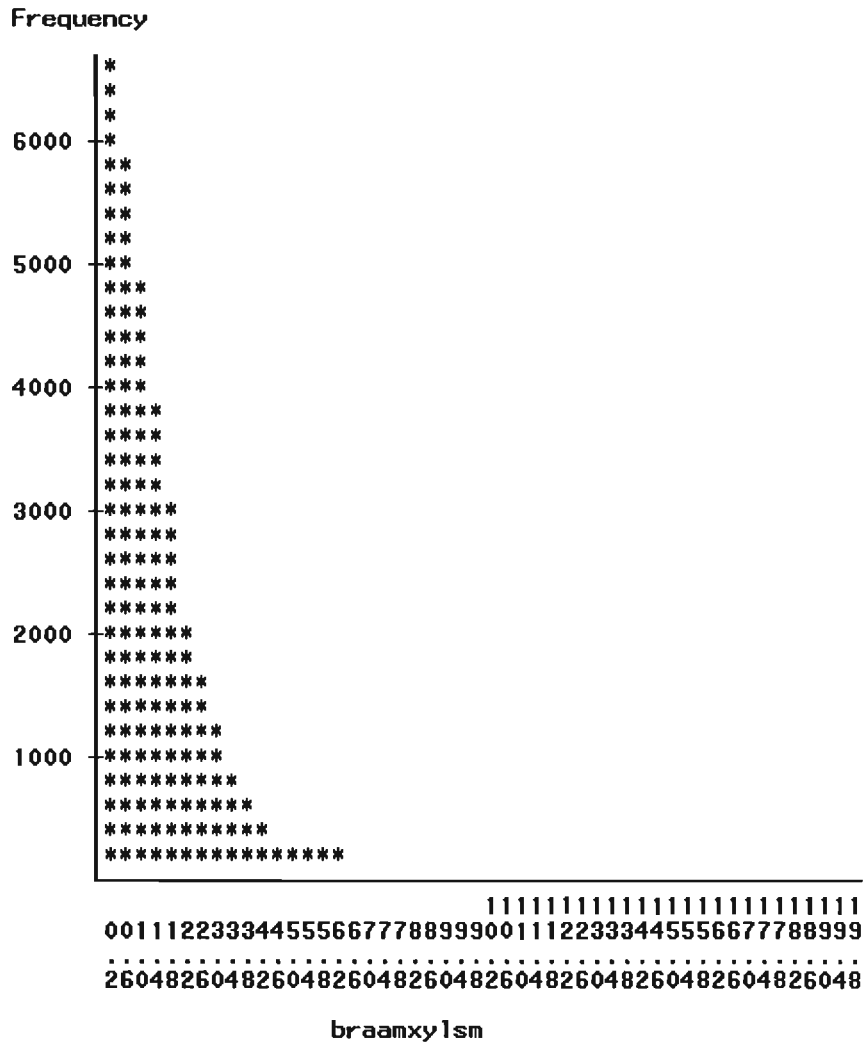


ptamxylsm

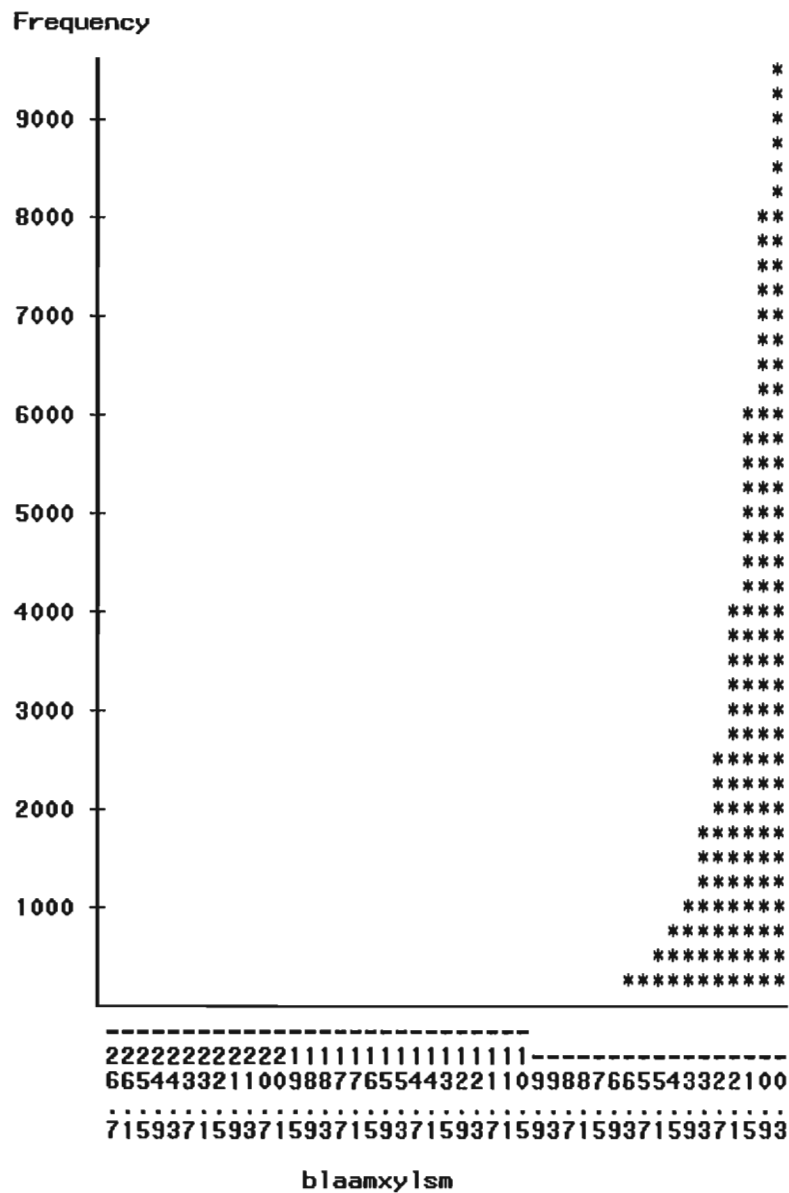
Variable Full Name: Box Asymmetry at Absolute Maximum XY*Lift Static Moment
(Degrees)
Abbreviated Name: baamxylsm



Variable Full Name: Box Rightward X Acceleration at Absolute Maximum XY*Lift
Static Moment (m/s^2)
Abbreviated Name: braamxylsm

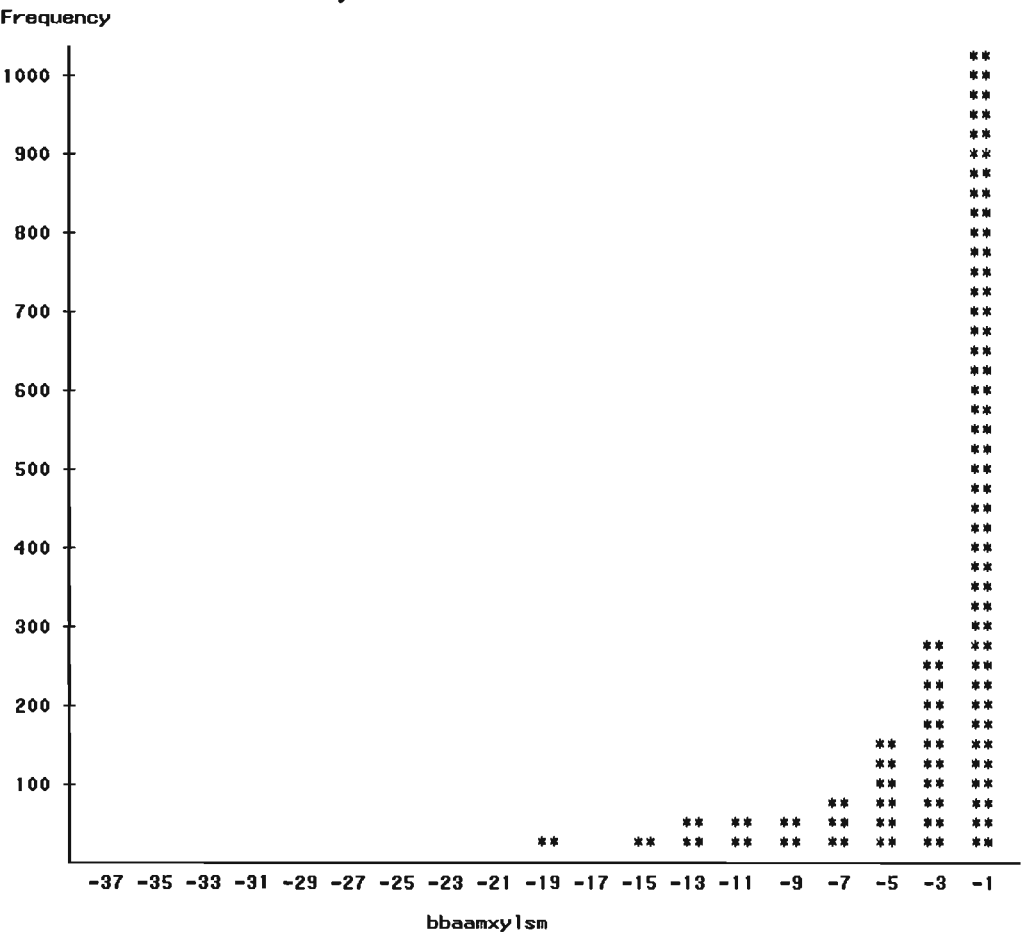


Variable Full Name: Box Leftward X Acceleration at Absolute Maximum XY*Lift Static Moment (m/s^2)
Abbreviated Name: blaamxylsm

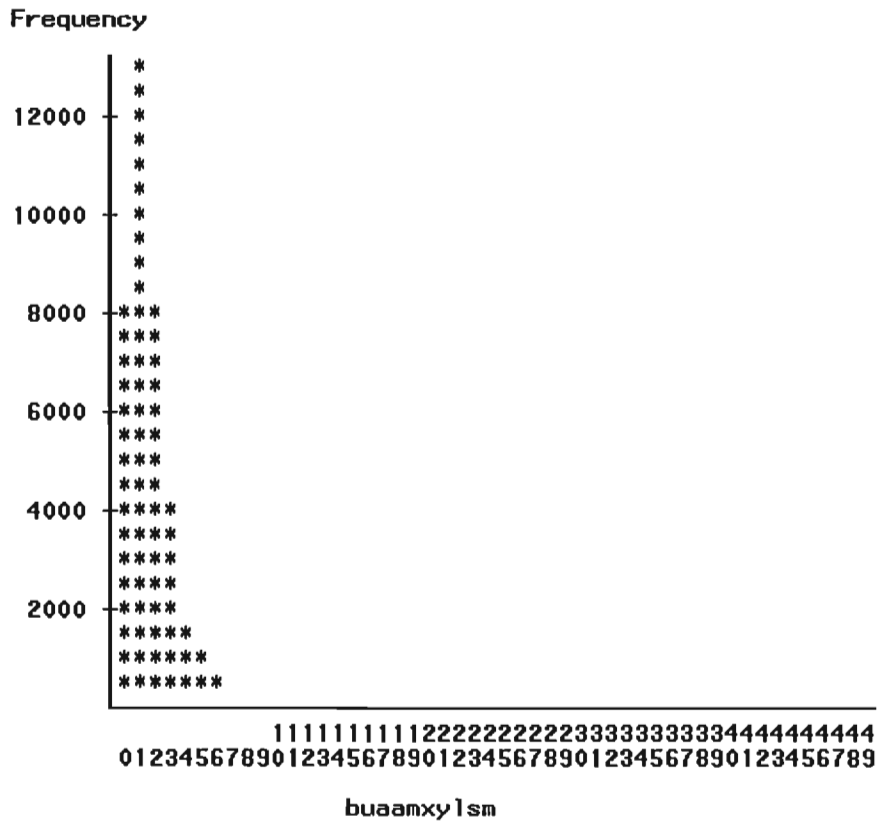




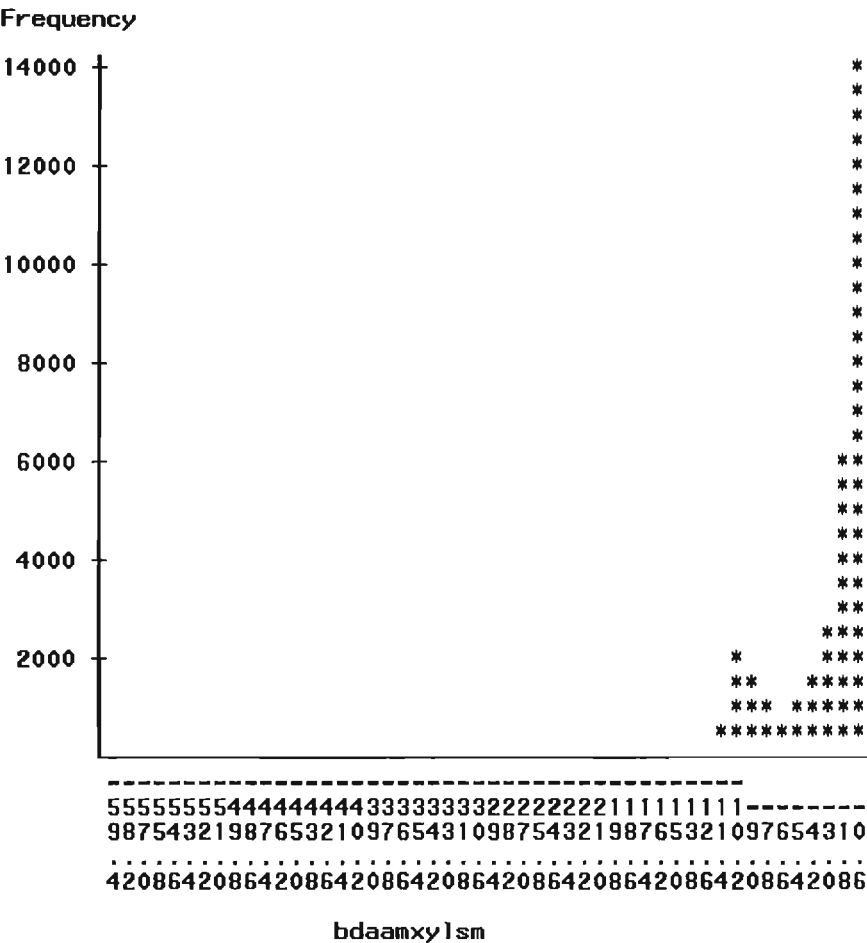
Variable Full Name: Box Backward Y Acceleration at Absolute Maximum XY*Lift
Static Moment (m/s^2)
Abbreviated Name: bbaamxylsm



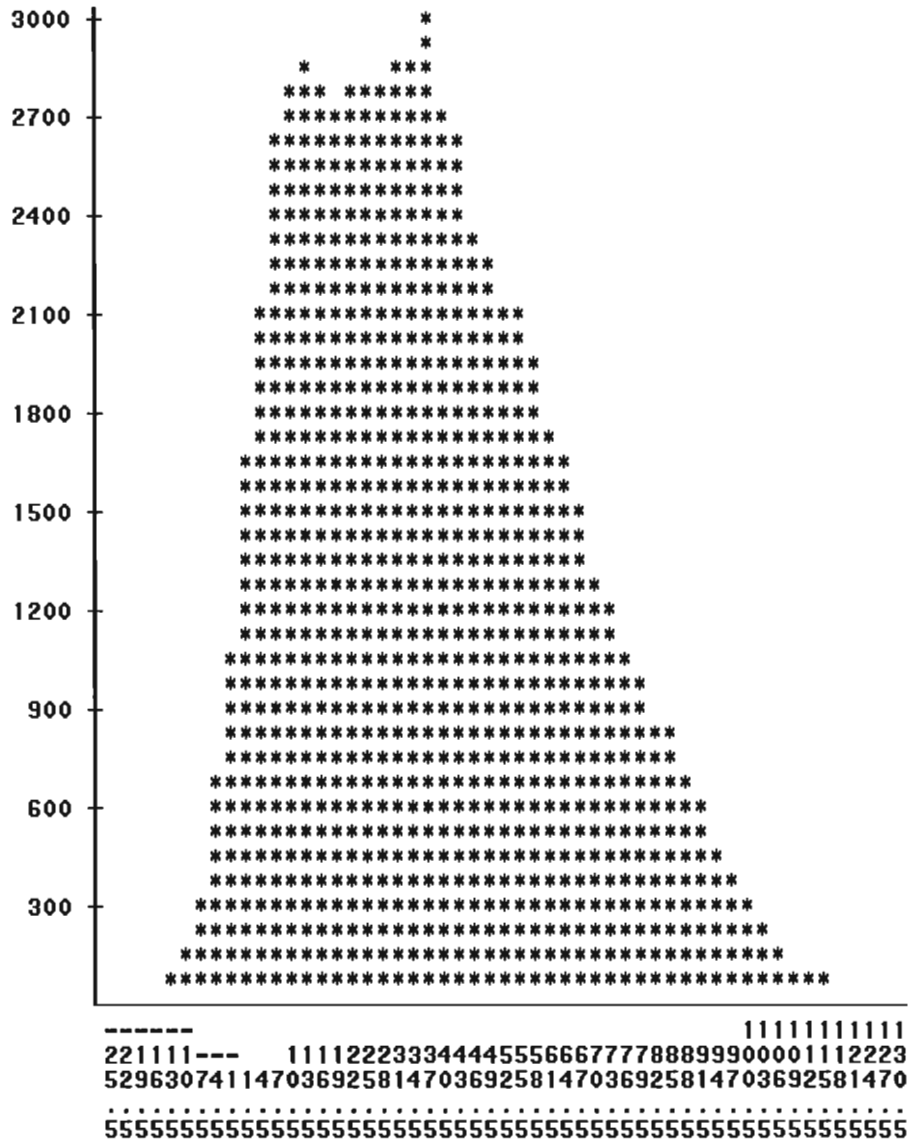
Abbreviated Name: **buaamxylsm**



Variable Full Name: Box Down Z Acceleration at Absolute Maximum XY* Lift Static
Moment (m/s^2)
Abbreviated Name: bdaamxylsm

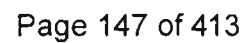


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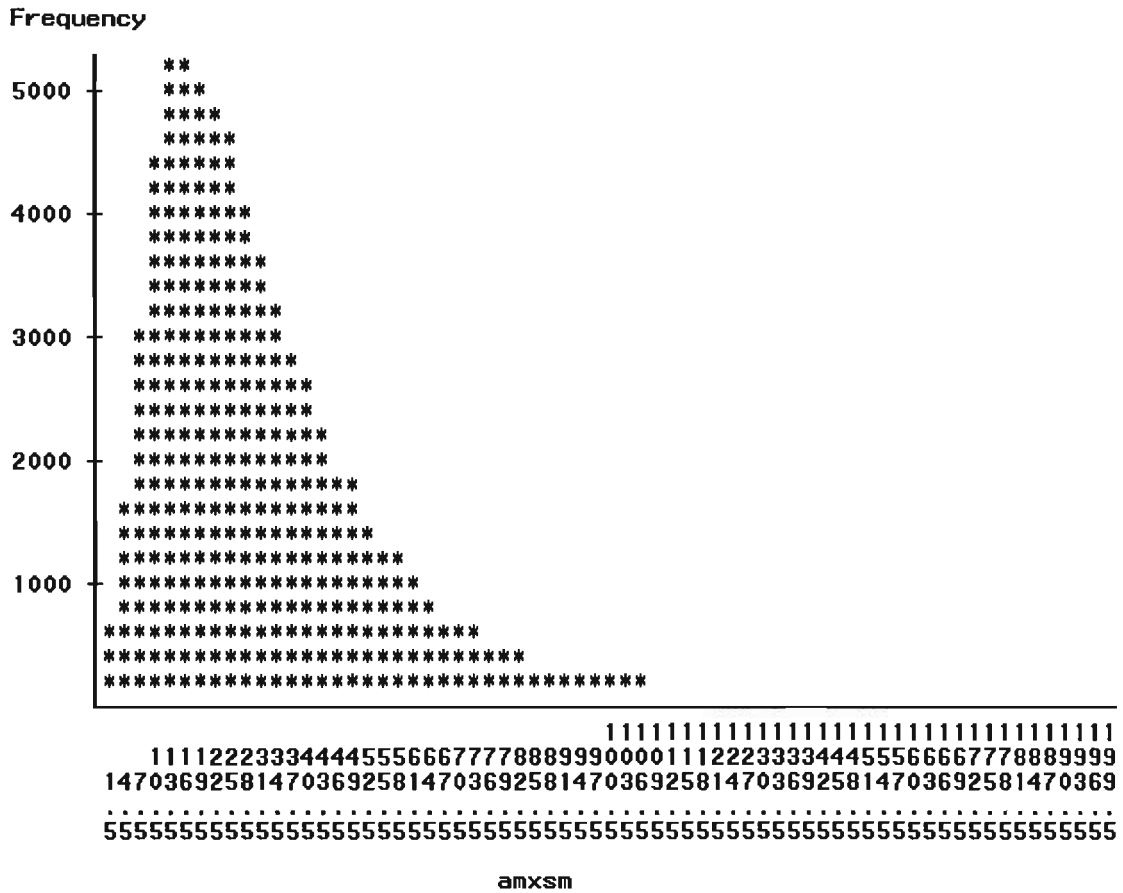


staamxylsm

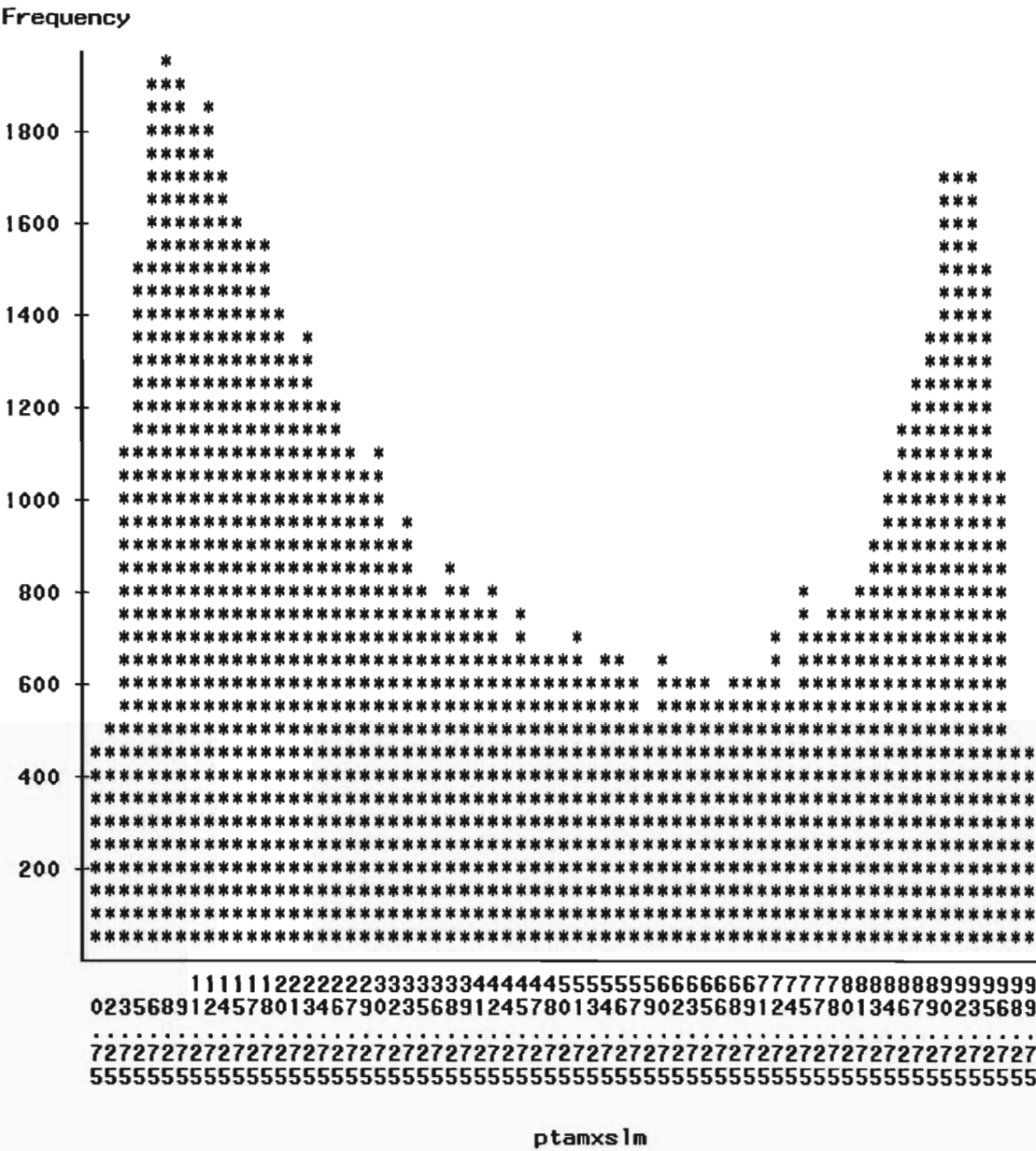
Abbreviated Name: aaxysm



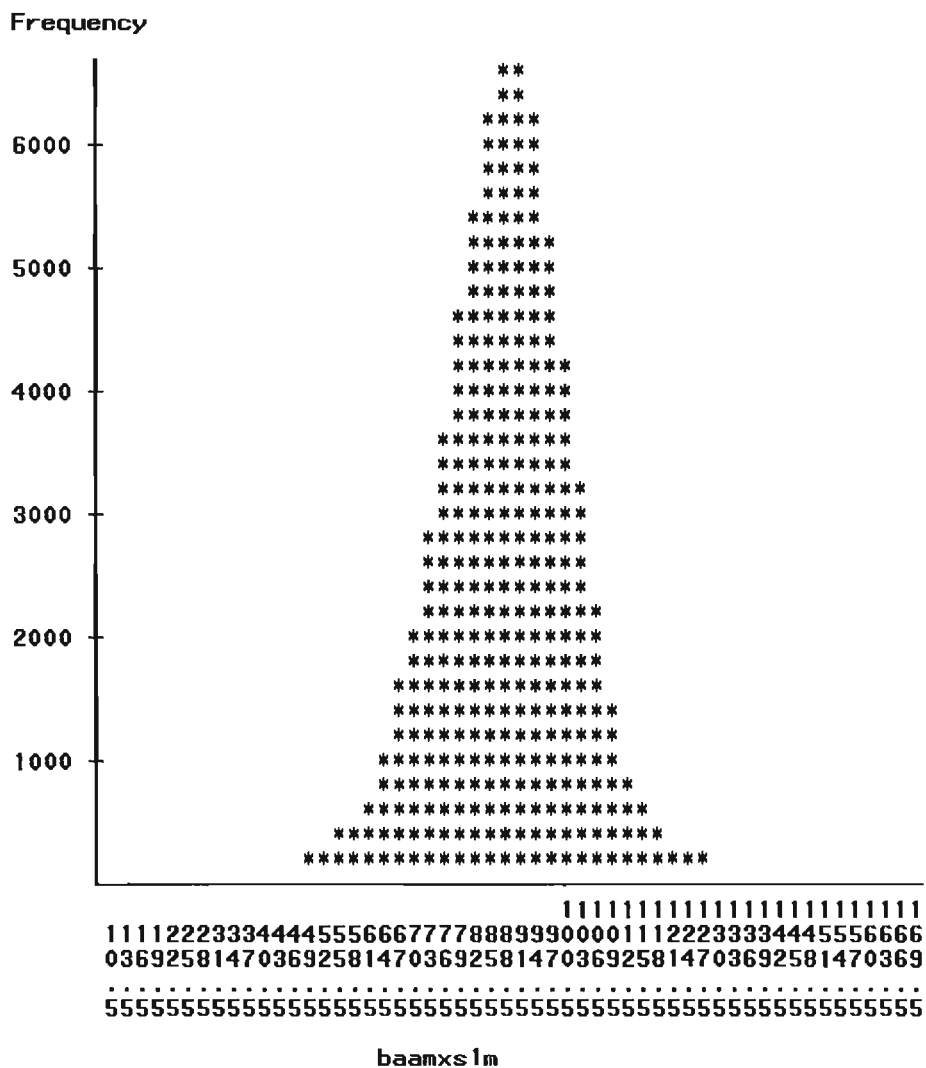
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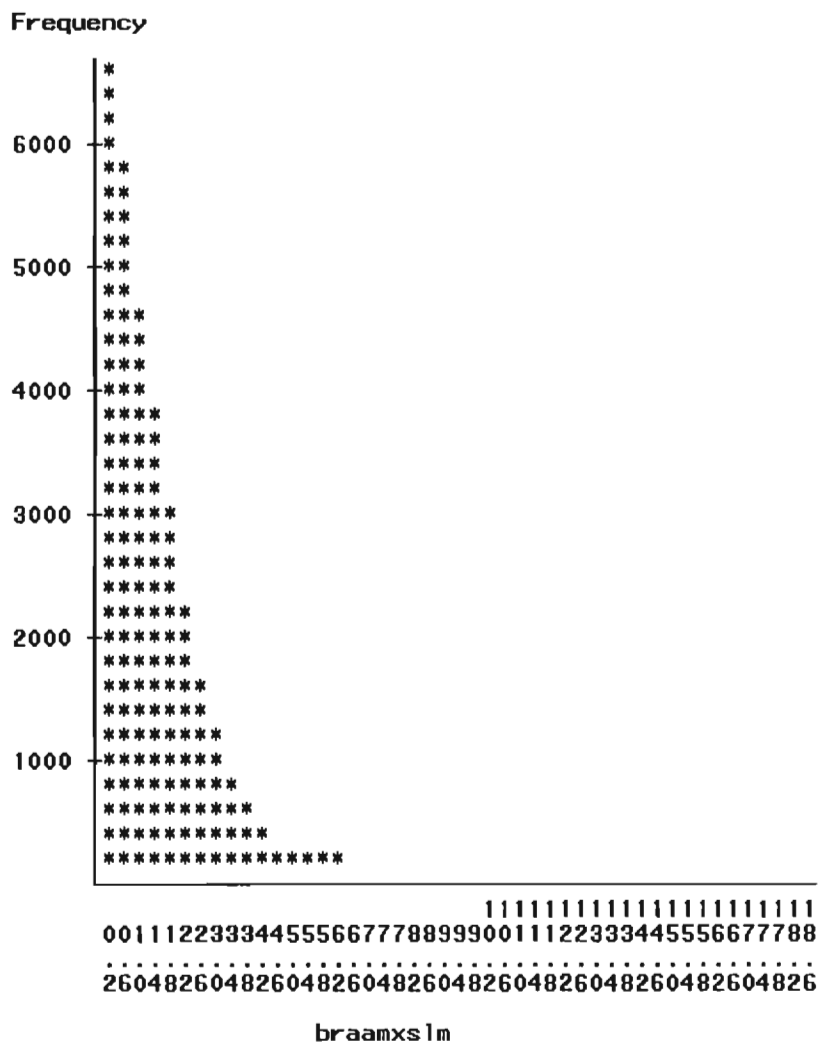
Variable Full Name: Percent Time of Absolute Maximum X-axis Static Lift Moment (%)
Abbreviated Name: ptamxslm



Abbreviated Name: baamxslm



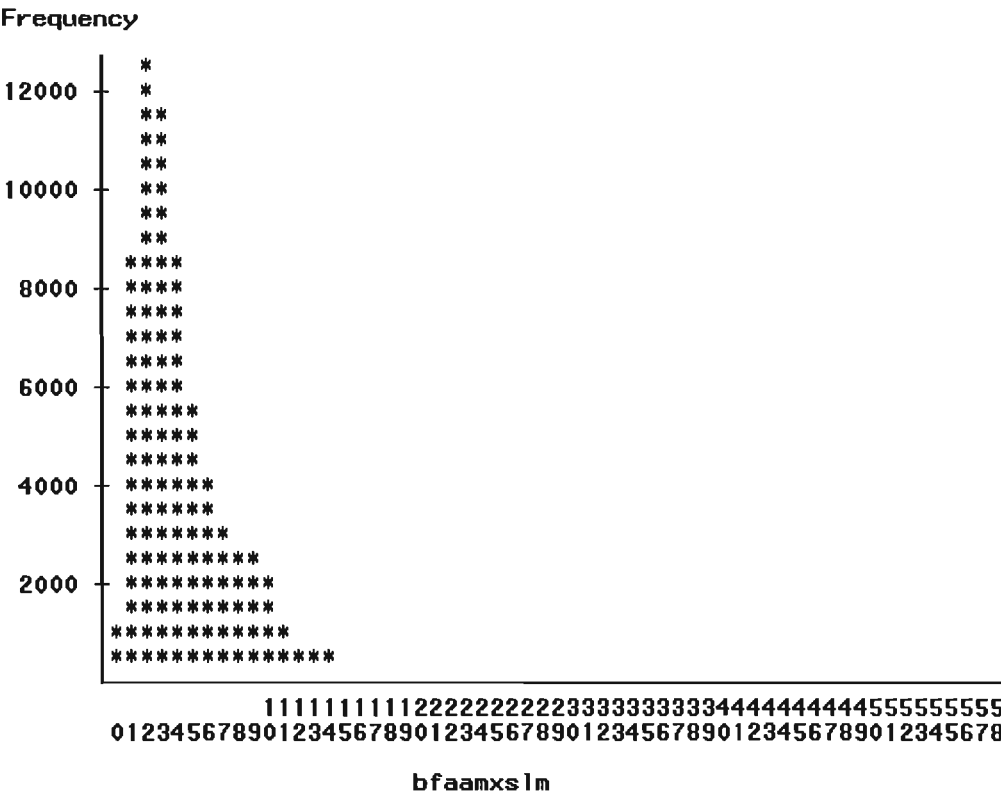
Variable Full Name: Box Rightward X Acceleration at Absolute Maximum X-axis Static Moment (m/s²)
Abbreviated Name: braamxslm



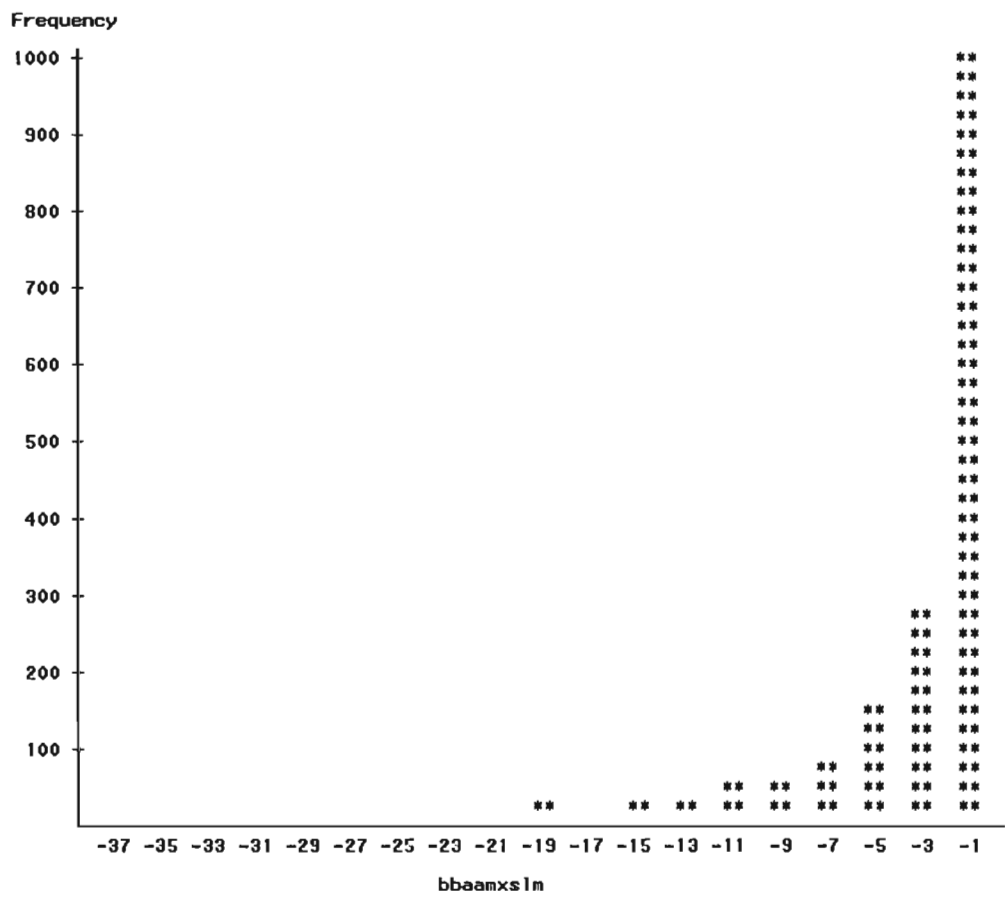
Abbreviated Name: blaamxslm



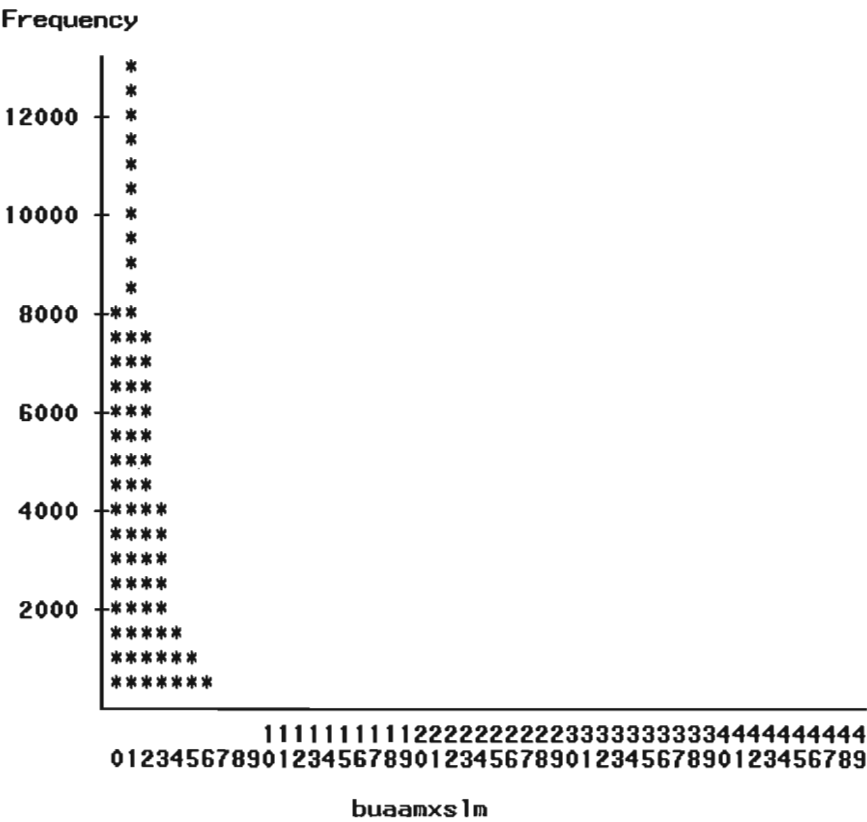
Variable Full Name: Box Forward Y Acceleration at Absolute Maximum X-axis Static
Moment (m/s^2)
Abbreviated Name: bfaamxslm



Variable Full Name: Box Backward Y Acceleration at Absolute Maximum X-axis Static
Moment (m/s^2)
Abbreviated Name: bbaamxslm



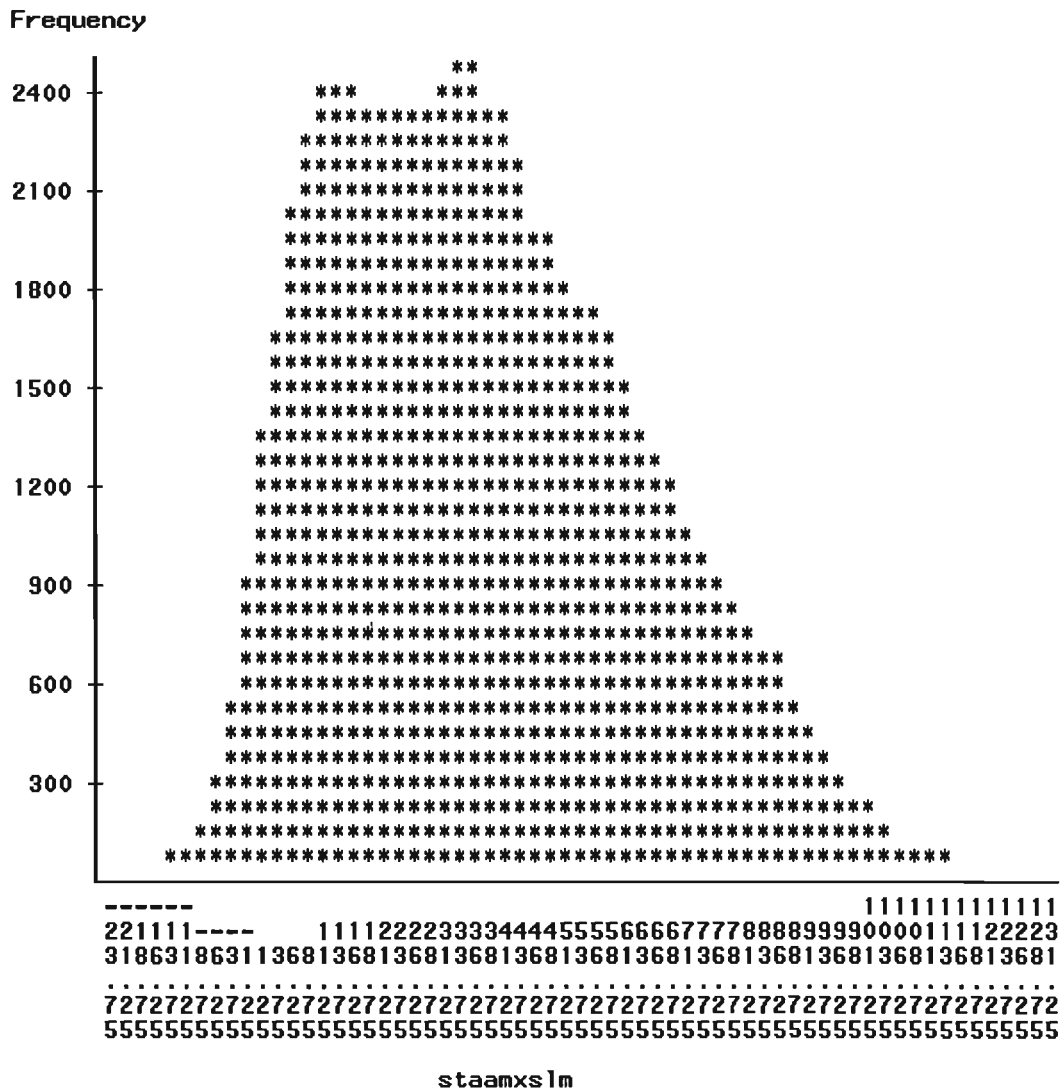
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Moment (m/s^2)
Abbreviated Name: buaamxslm



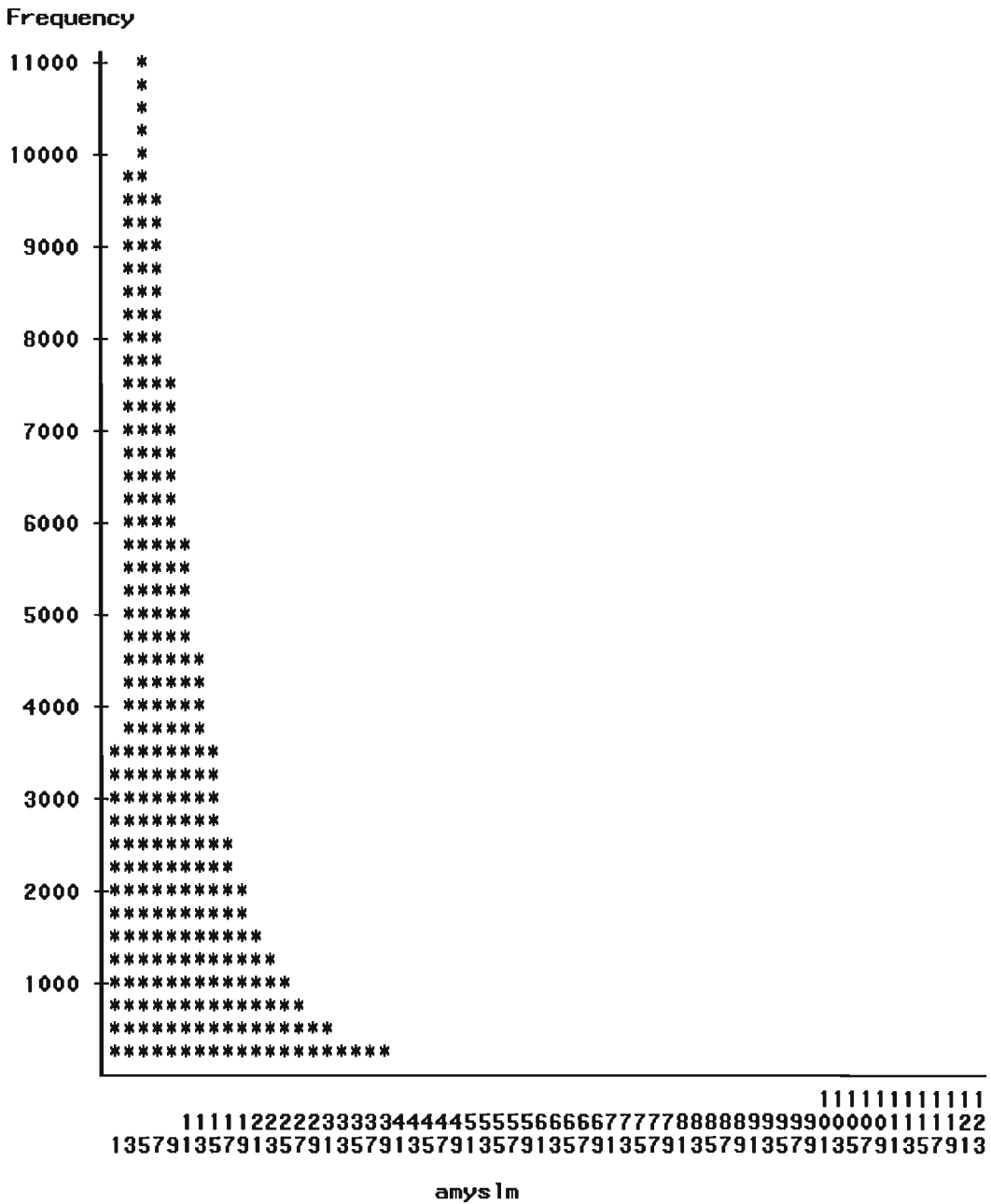
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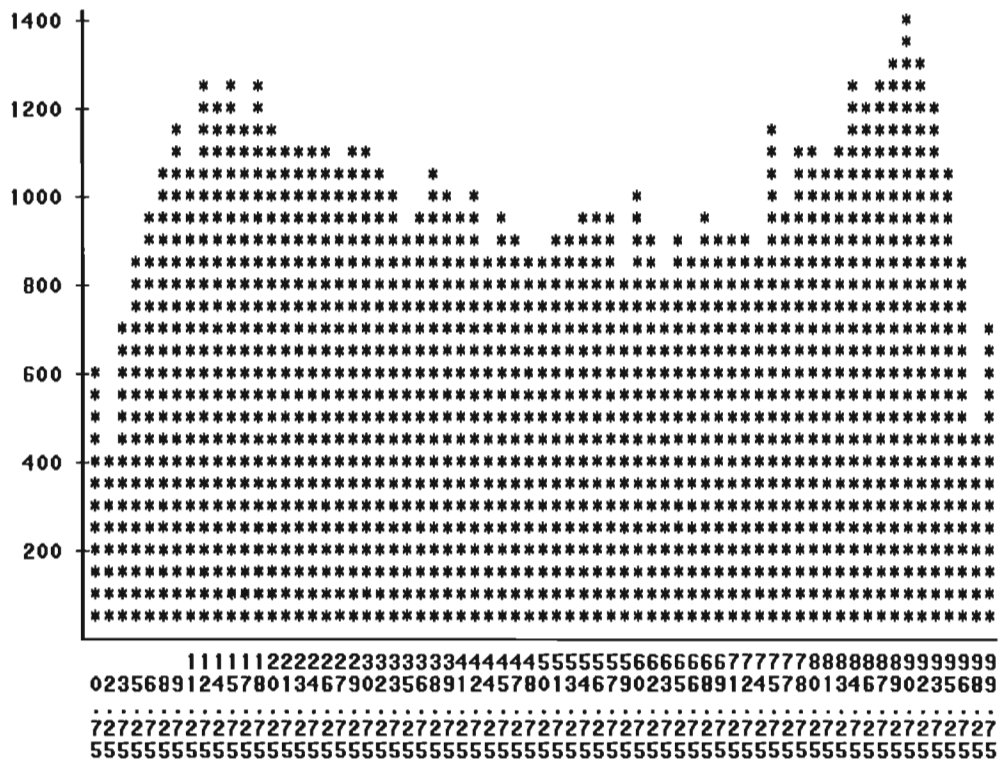
Variable Full Name: Sagittal Trunk Angle at Absolute Maximum X-axis Static Lift Moment (Degrees)
Abbreviated Name: staamxslm



Variable Full Name: Absolute Maximum Y-axis Static Lift Moment (N*m)
Abbreviated Name: amyslm

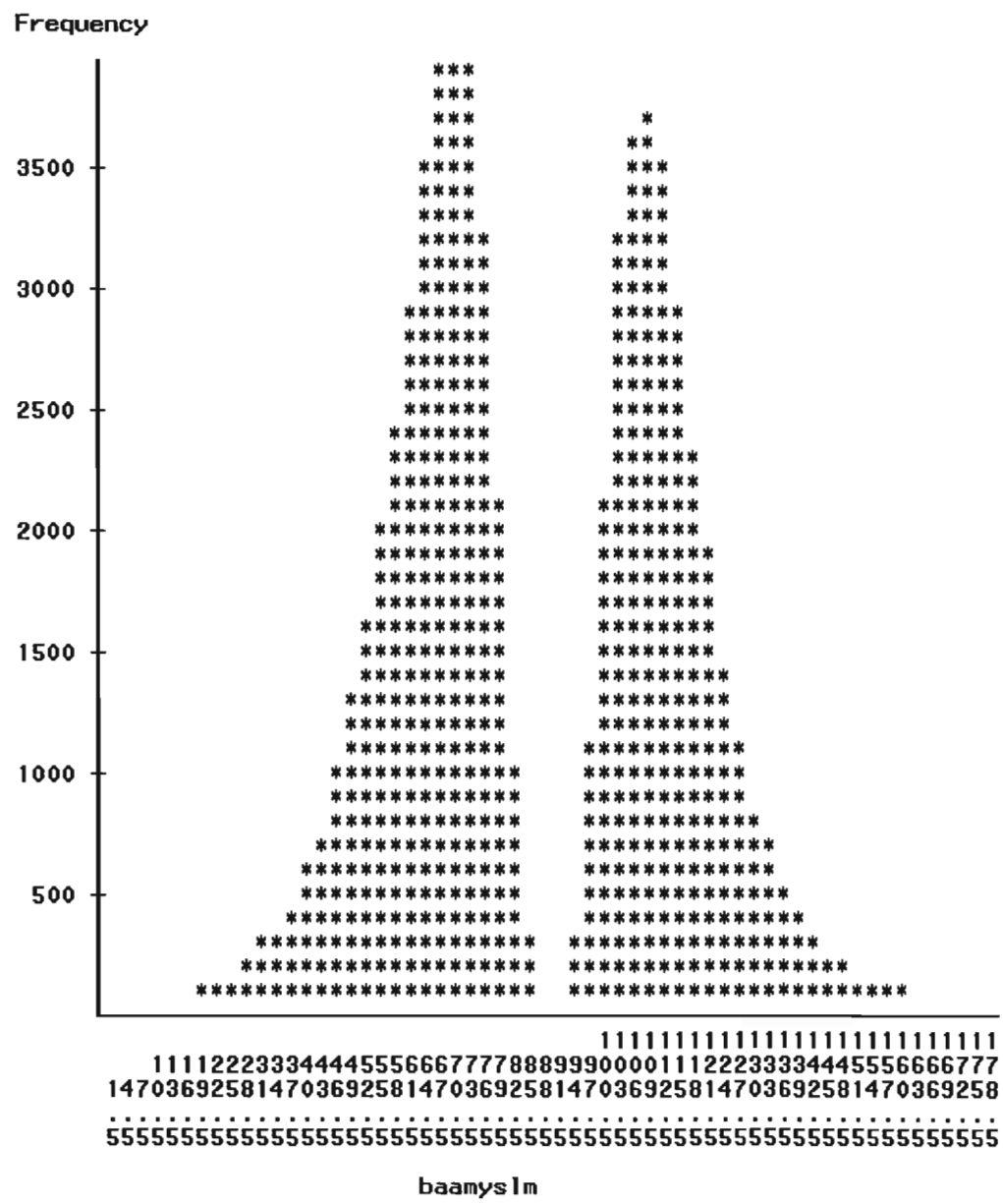


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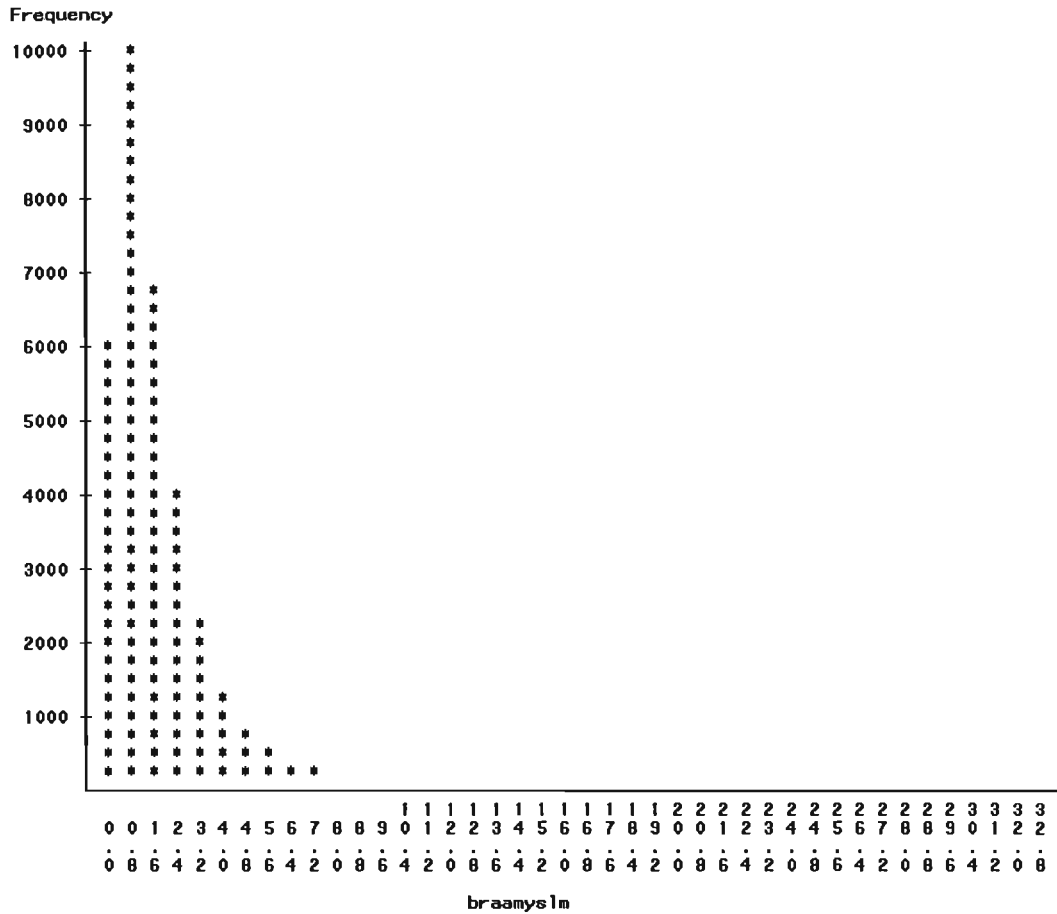


ptamysIm

Variable Full Name: Box Asymmetry at Absolute Maximum Y-axis Static Lift Moment (Degrees)
Abbreviated Name: baamyslm



Variable Full Name: Box Rightward X Acceleration at Absolute Maximum Y-axis
Static Moment (m/s^2)
Abbreviated Name: braamyslm



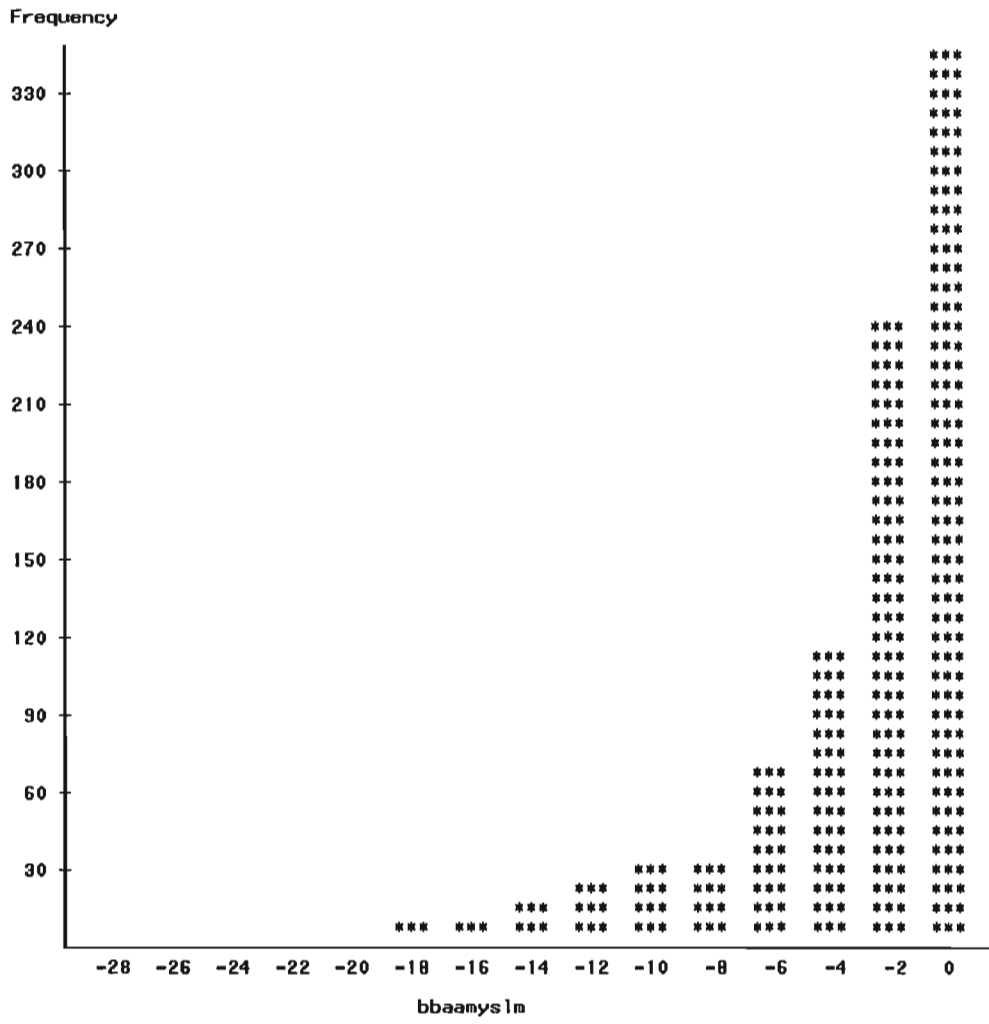
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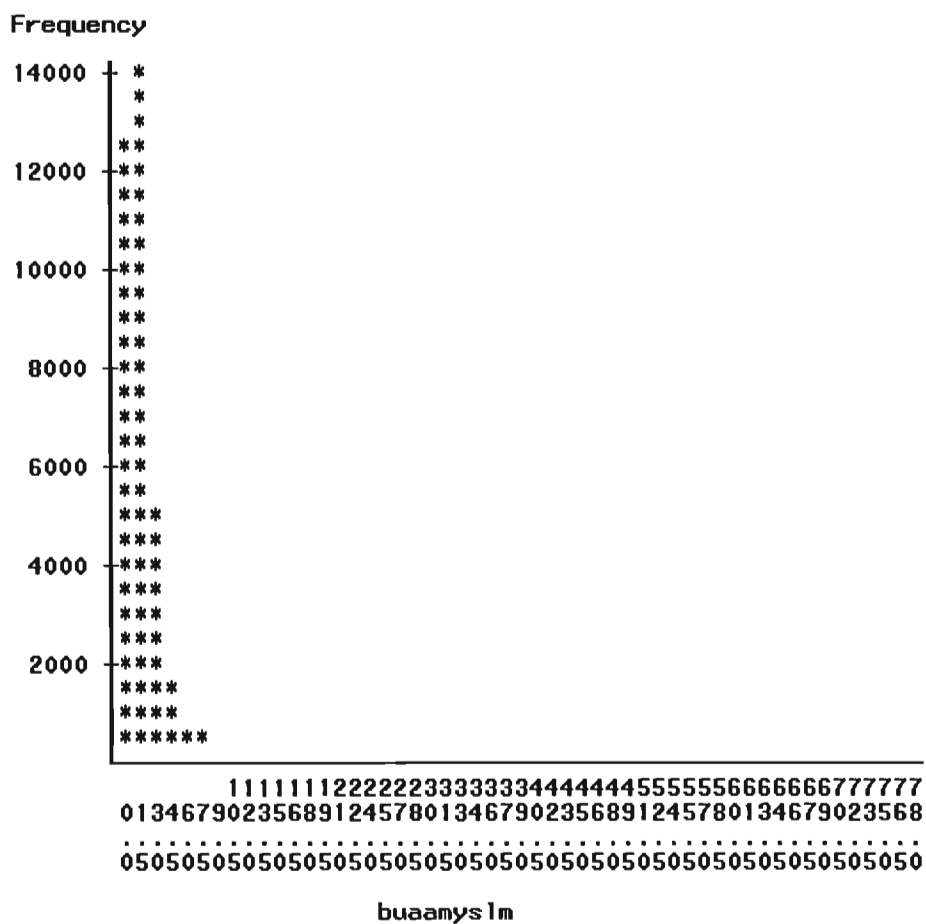
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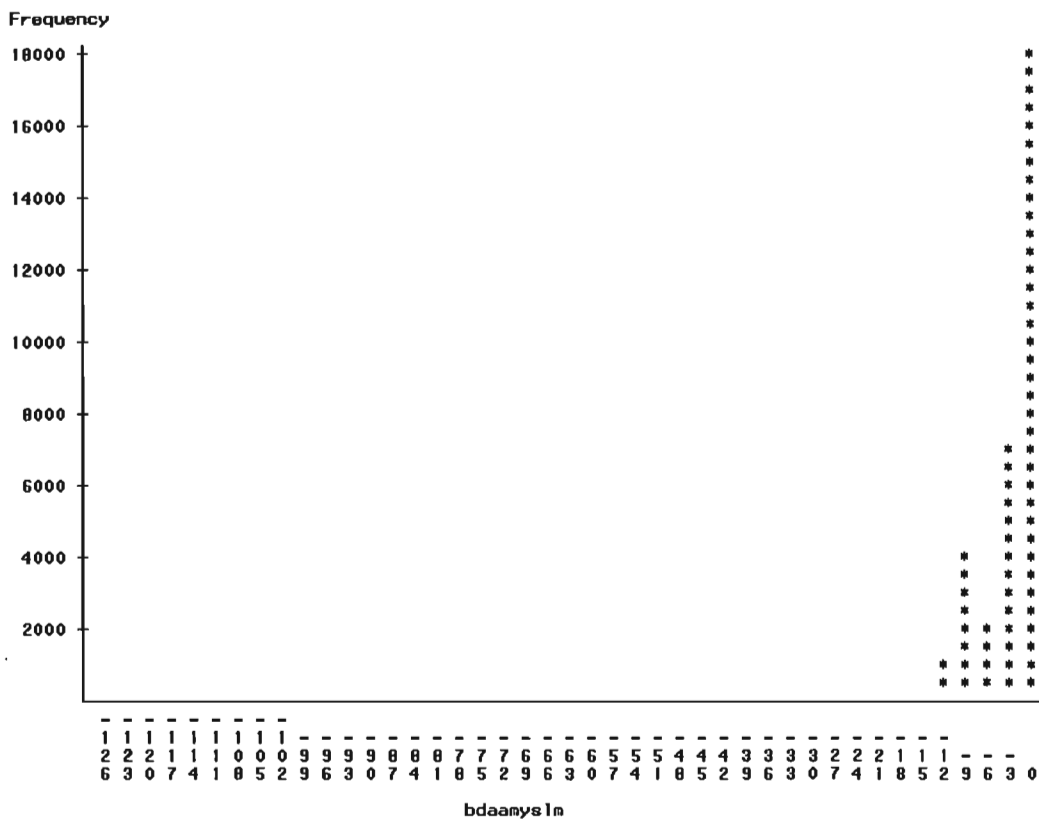
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Moment (m/s^2)
Abbreviated Name: bbaamyslm



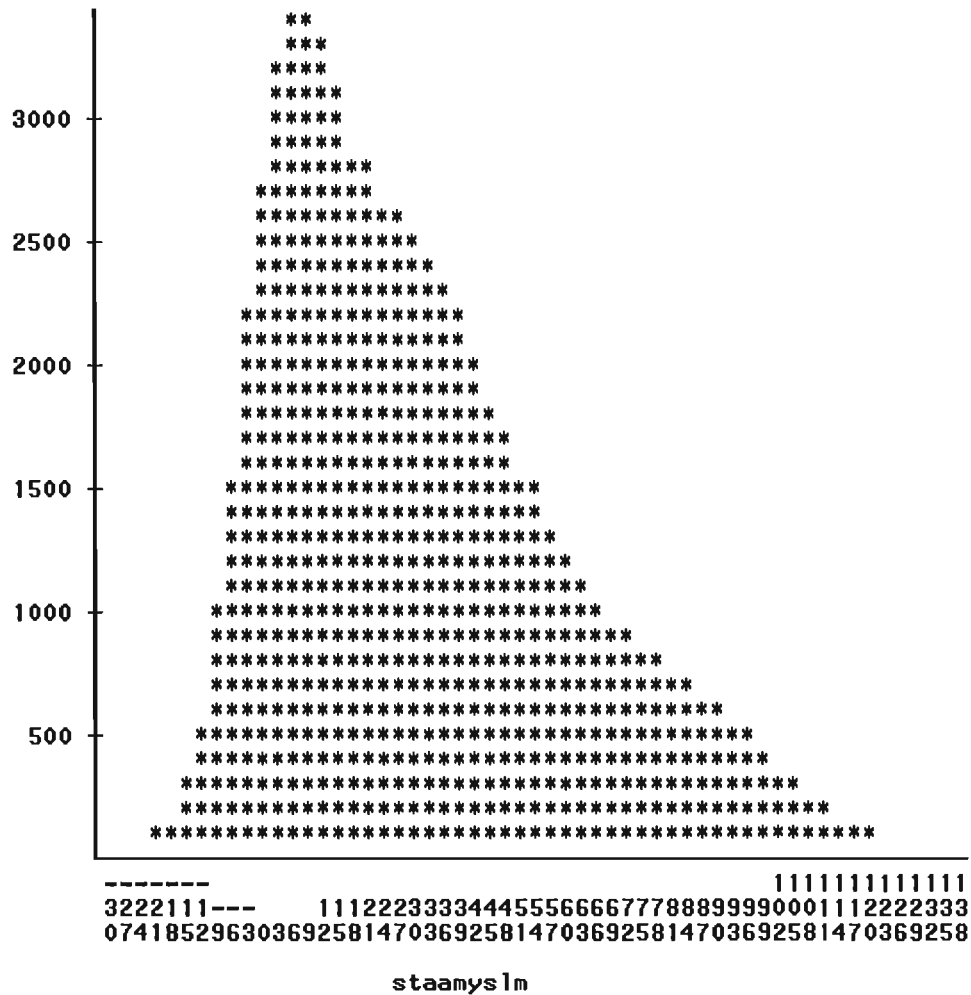
Abbreviated Name: buaamyslm



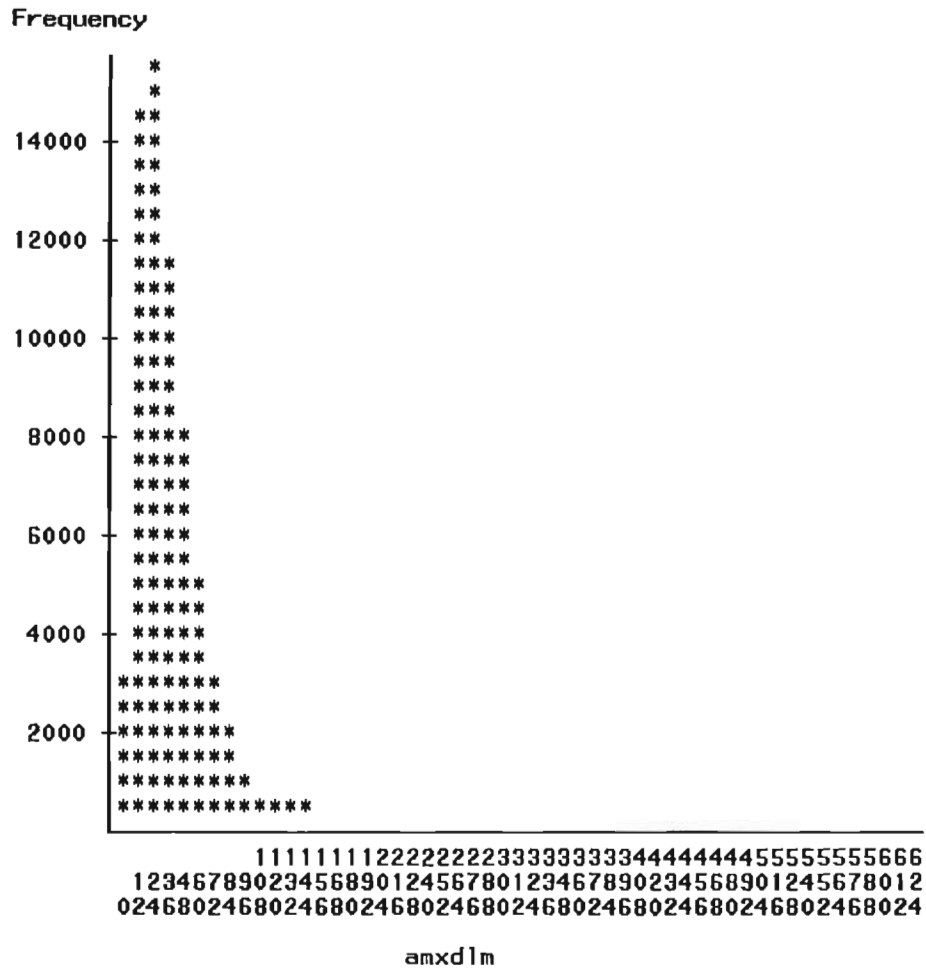
Variable Full Name: Box Down Z Acceleration at Absolute Maximum Y-axis Static
Moment (m/s^2)
Abbreviated Name: bdaamyslm



Frequency

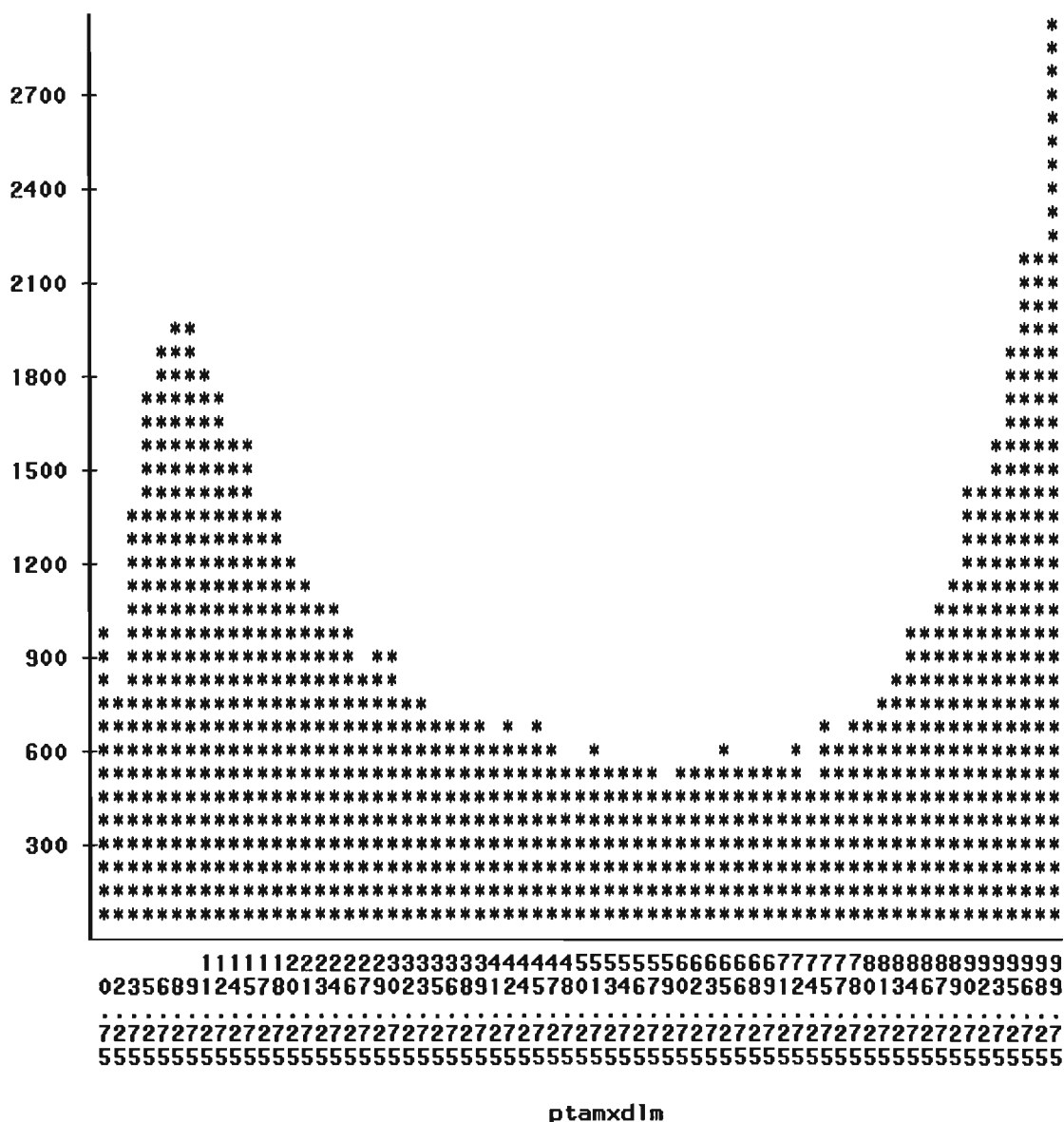


Variable Full Name: Absolute Maximum X-axis Dynamic Lift Moment (N*m)
 Abbreviated Name: amxdlm

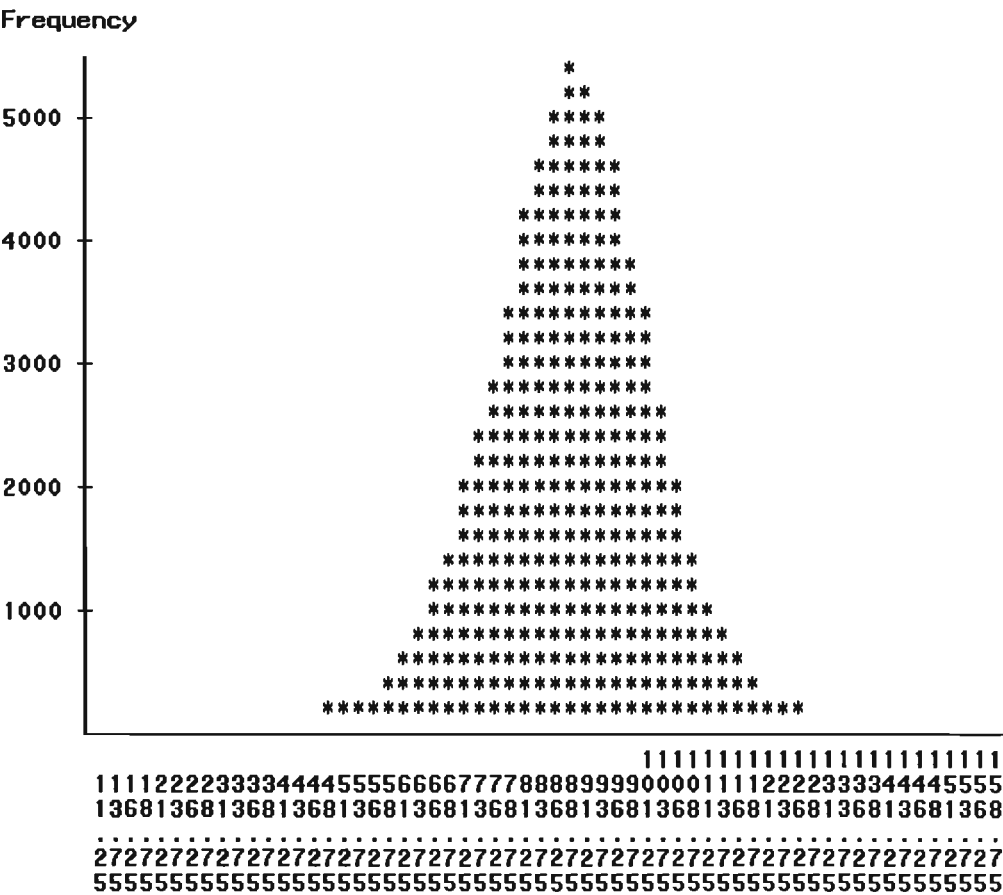


Abbreviated Name: ptamxdlm

Frequency



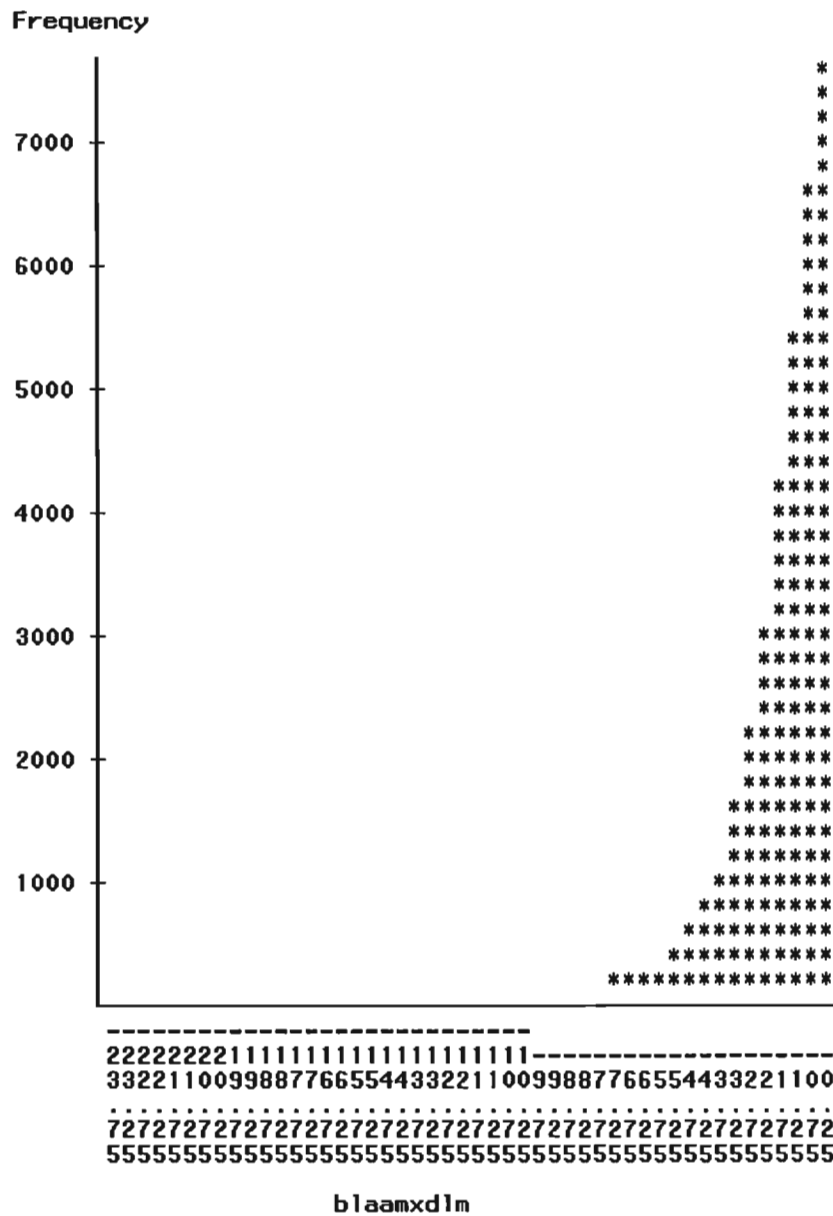
Variable Full Name: Box Asymmetry at Absolute Maximum X-axis Dynamic Lift
Moment (Degrees)
Abbreviated Name: baamxdlm



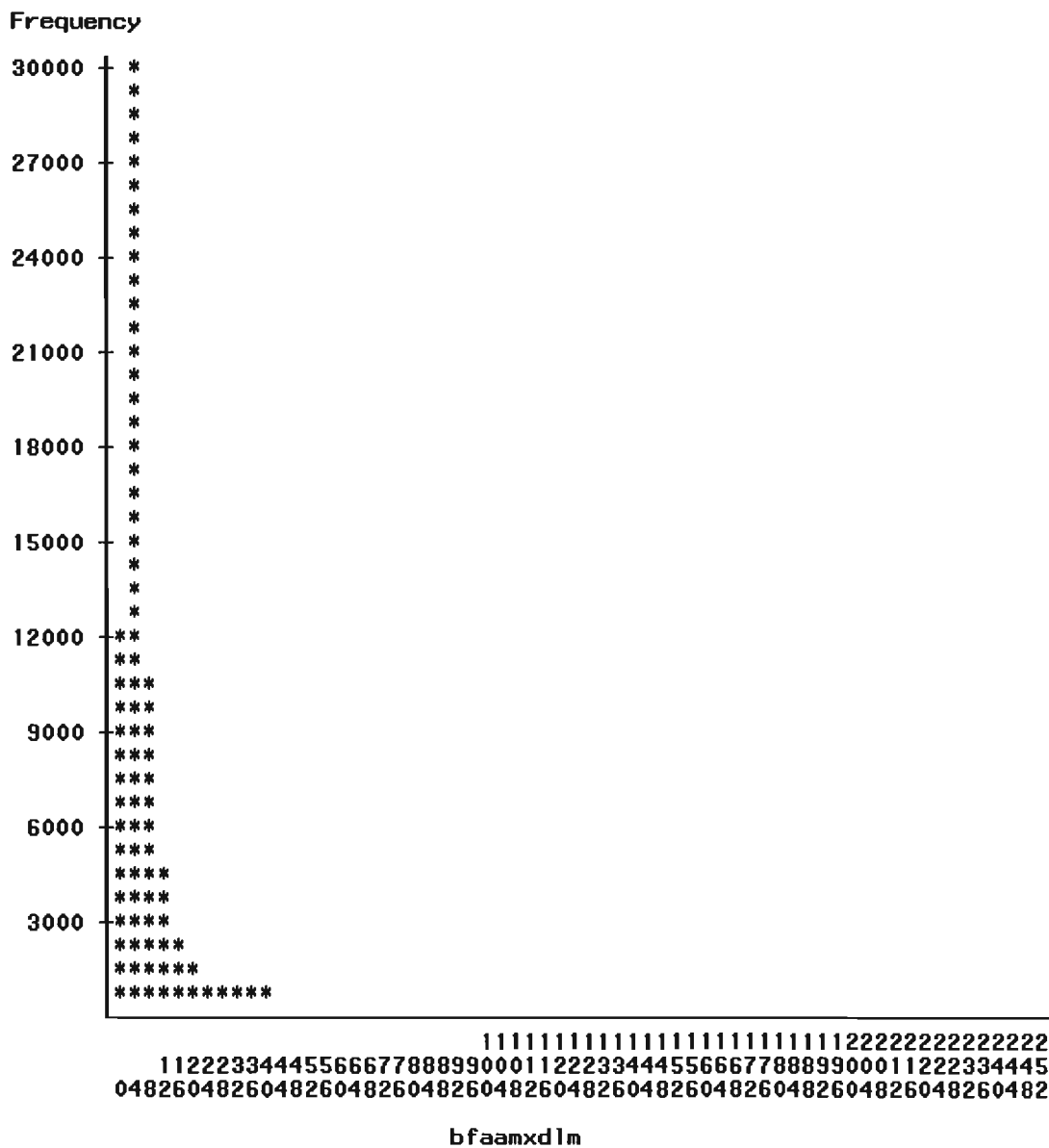
Frequency

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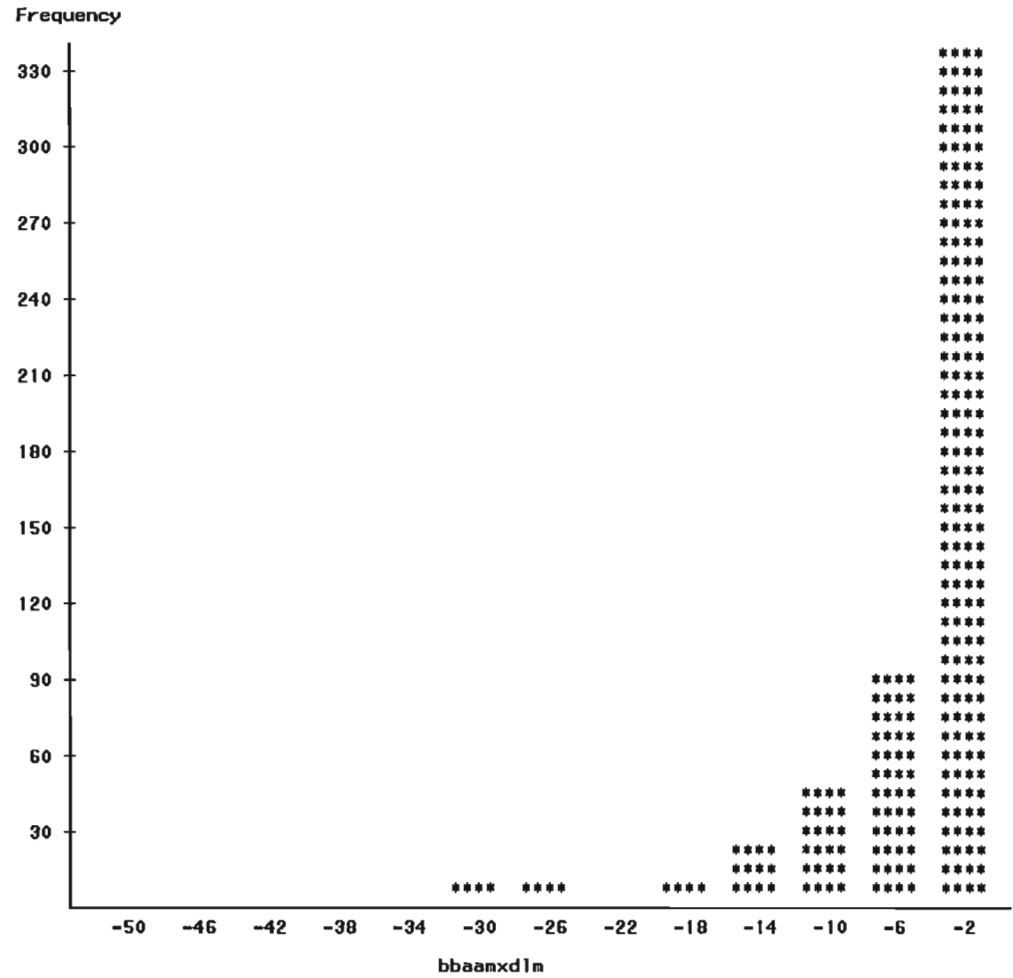
Variable Full Name: Box Leftward X Acceleration at Absolute Maximum X-axis
Dynamic Moment (m/s²)
Abbreviated Name: blaamxdm



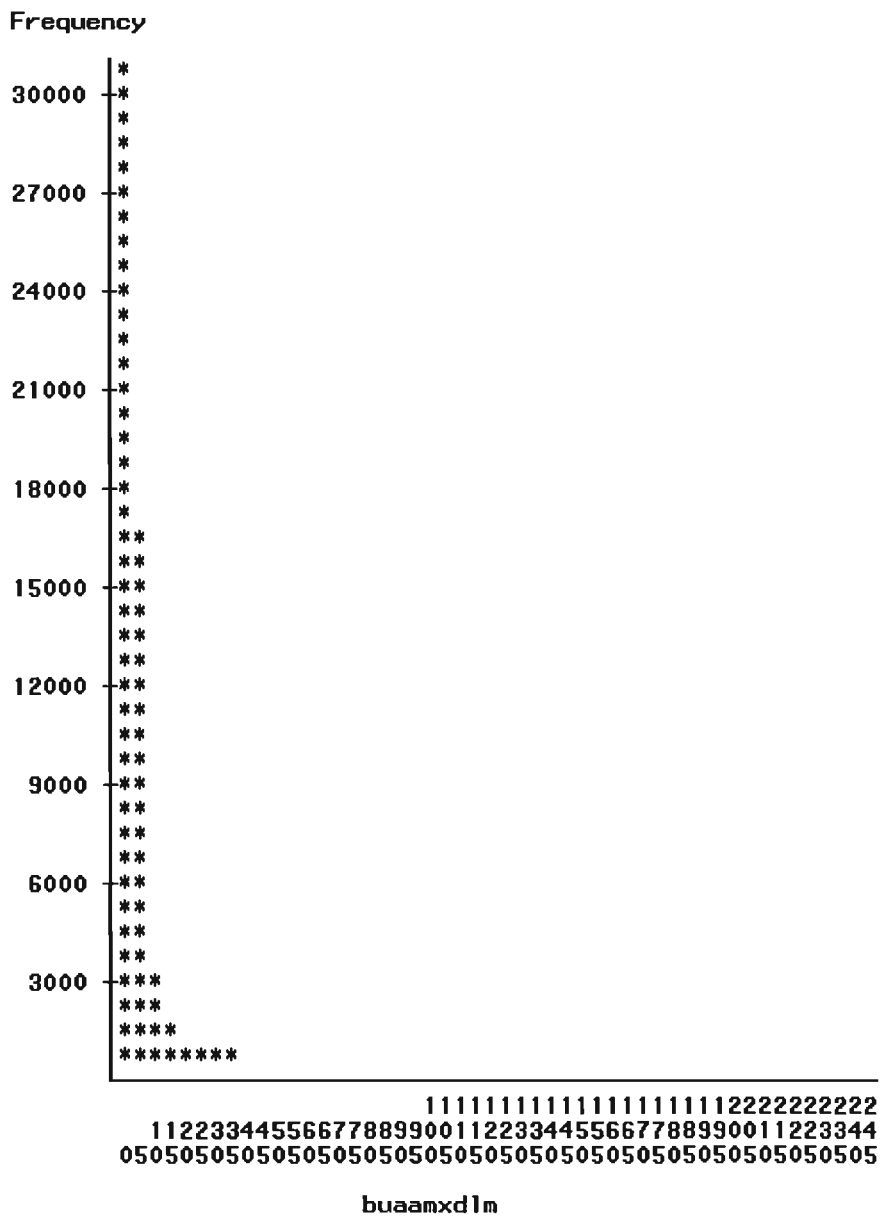
Variable Full Name: Box Forward Y Acceleration at Absolute Maximum X-axis
Dynamic Moment (m/s^2)
Abbreviated Name: bfaamxdm



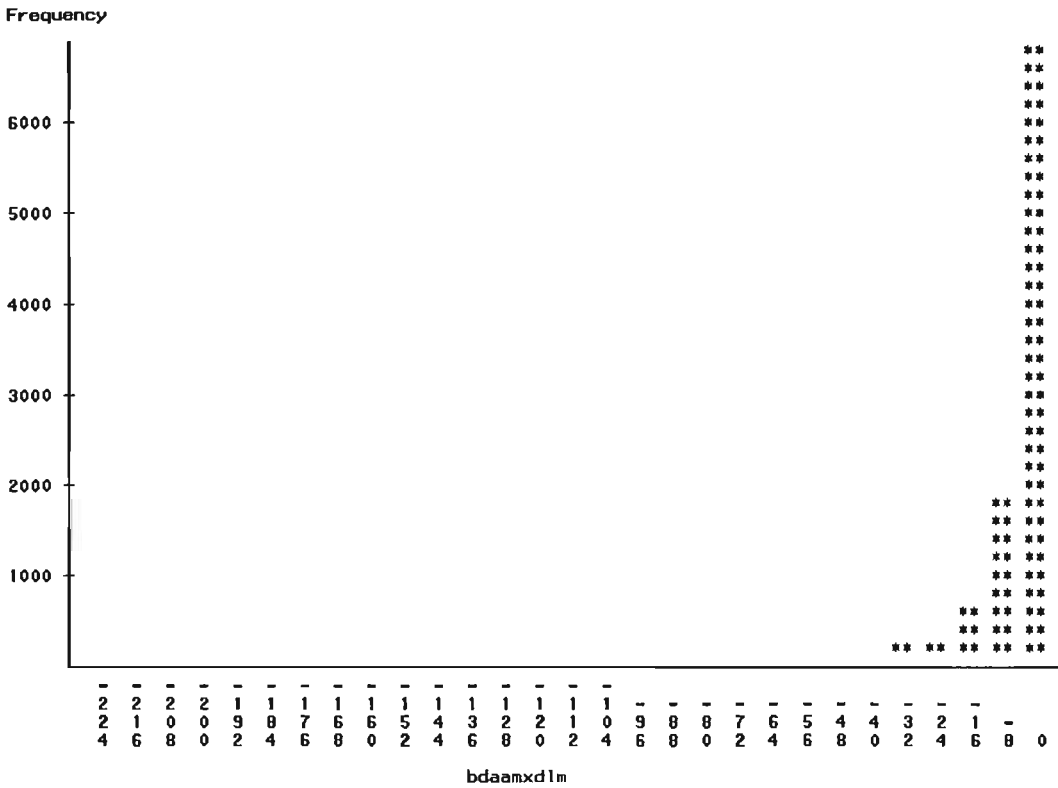
Variable Full Name: Box Backward Y Acceleration at Absolute Maximum X-axis
Dynamic Moment (m/s^2)
Abbreviated Name: bbaamxd1m



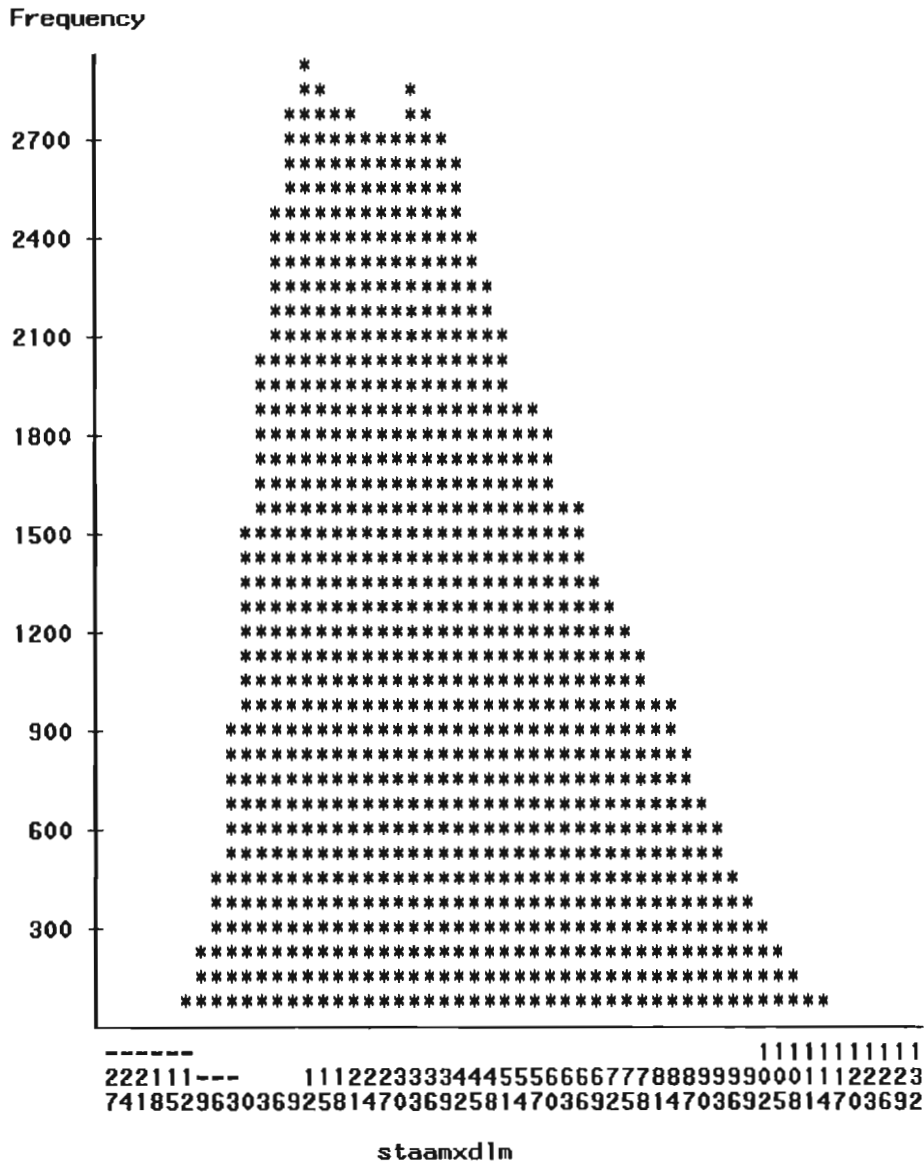
Variable Full Name: Box Up Z Acceleration at Absolute Maximum X-axis Dynamic
Moment (m/s^2)
Abbreviated Name: buaamxd1m



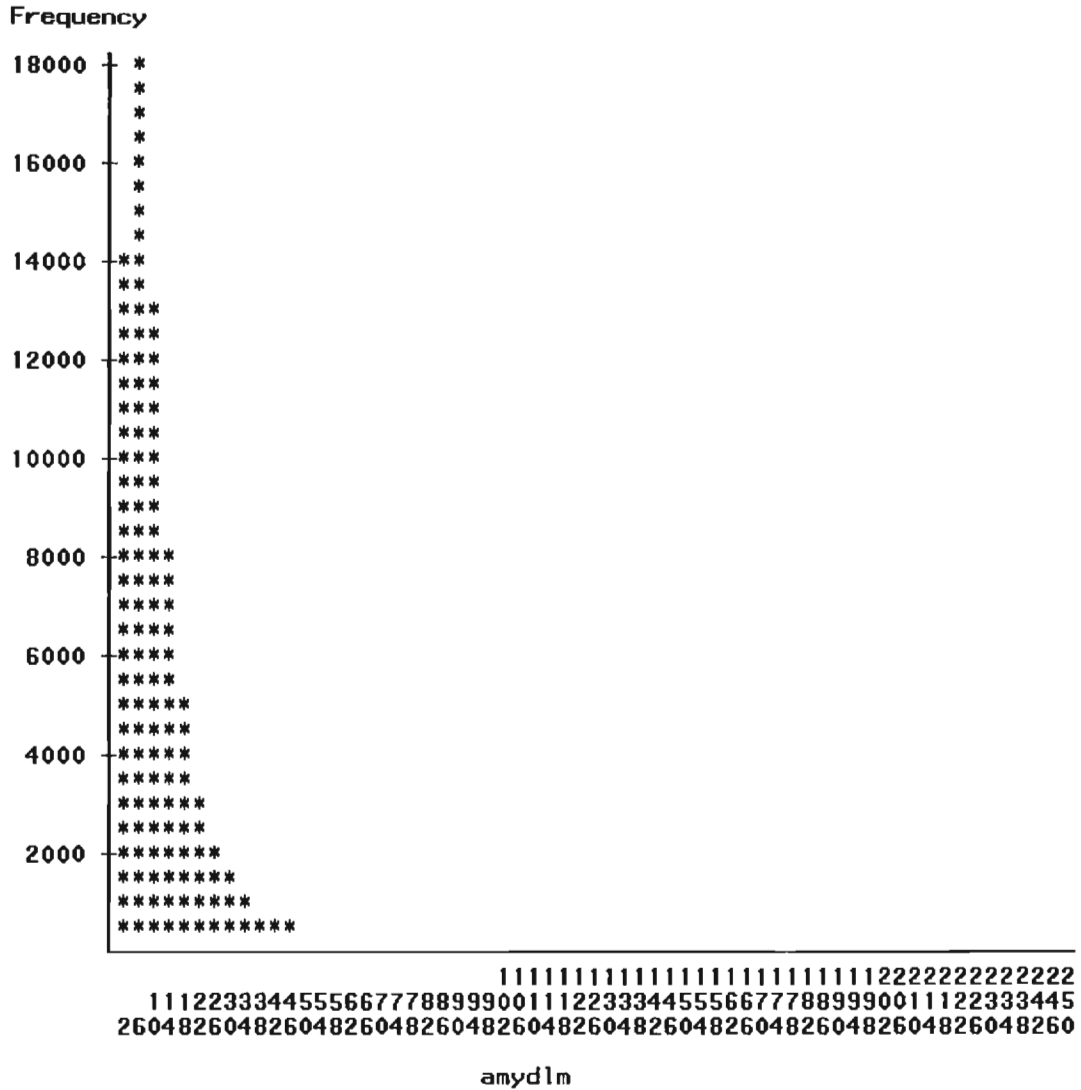
Variable Full Name: Box Down Z Acceleration at Absolute Maximum X-axis Dynamic
Moment (m/s^2)
Abbreviated Name: bdaamxd1m



Variable Full Name: Sagittal Trunk Angle at Absolute Maximum X-axis Dynamic Lift
 Moment (Degrees)
 Abbreviated Name: staamxdlm



Variable Full Name: Absolute Maximum Y-axis Dynamic Lift Moment (N*m)
 Abbreviated Name: amydlm

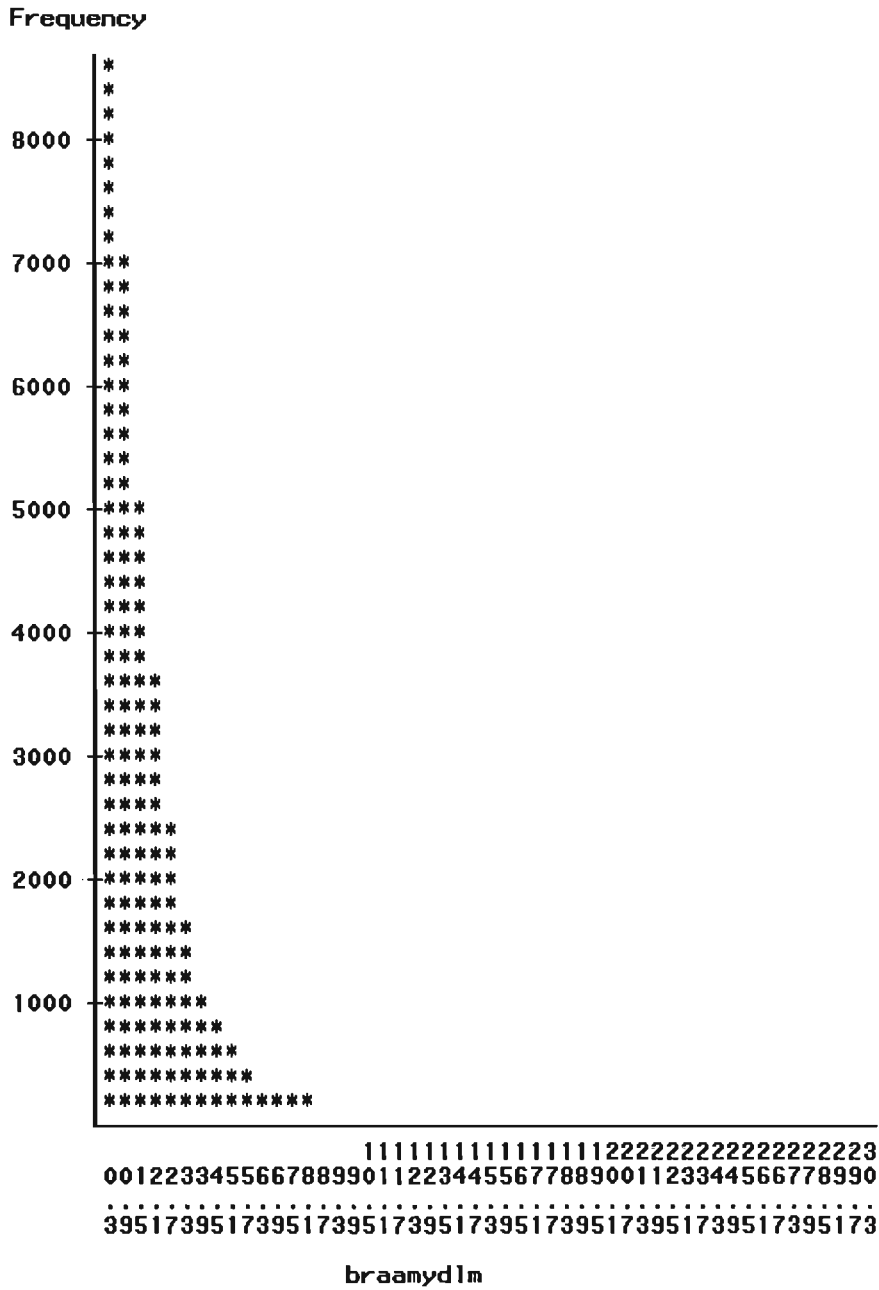


Abbreviated Name: ptamydlm

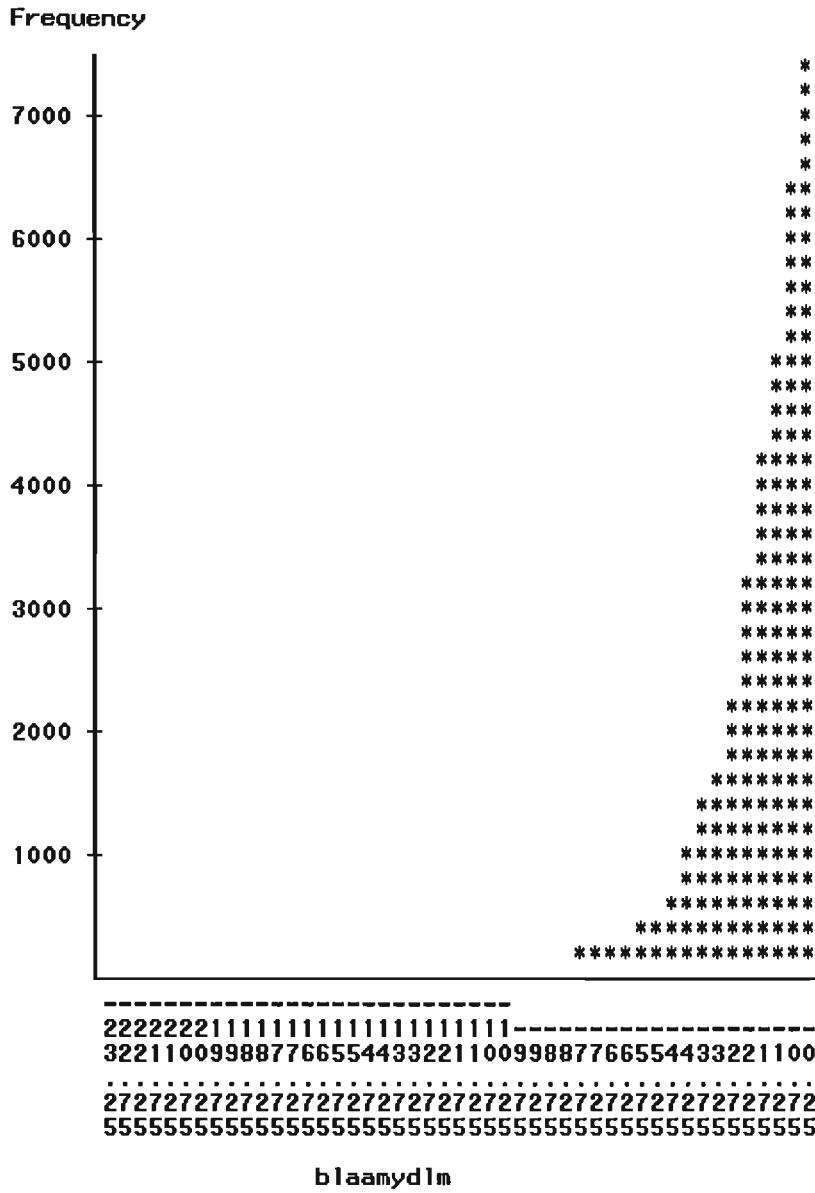
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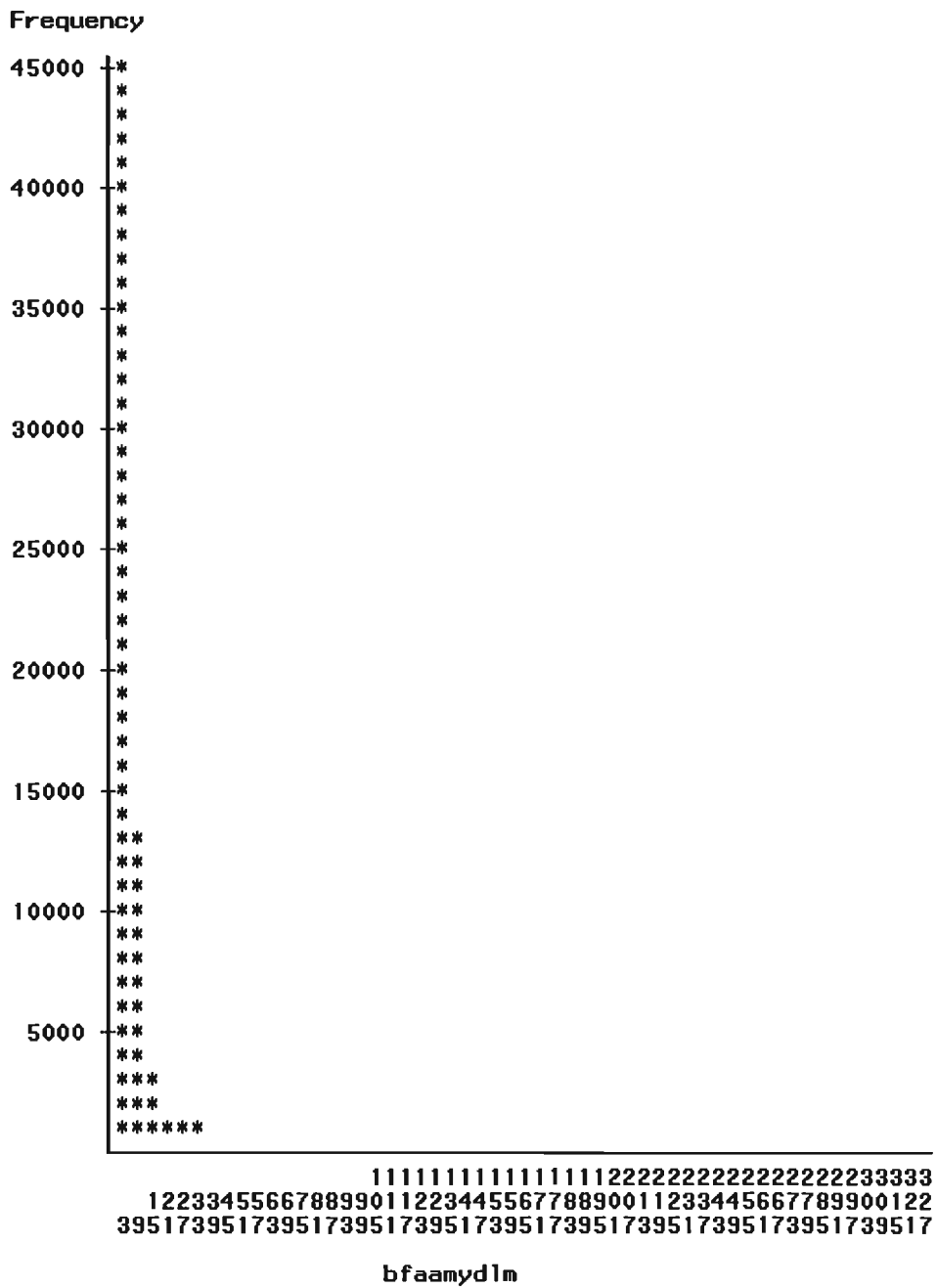
Variable Full Name: Box Rightward X Acceleration at Absolute Maximum Y-axis
Dynamic Moment (m/s^2)
Abbreviated Name: braamydlm



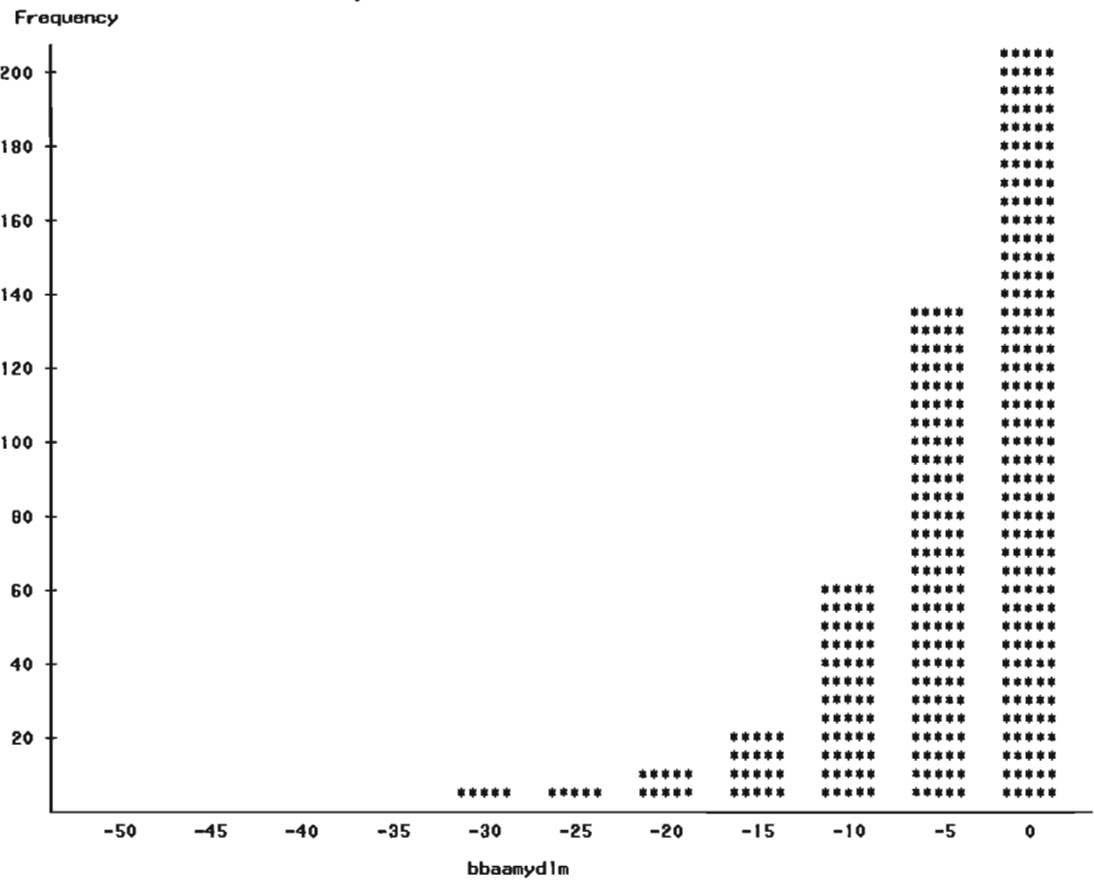
Variable Full Name: Box Leftward X Acceleration at Absolute Maximum Y-axis
Dynamic Moment (m/s²)
Abbreviated Name: blaamydlm



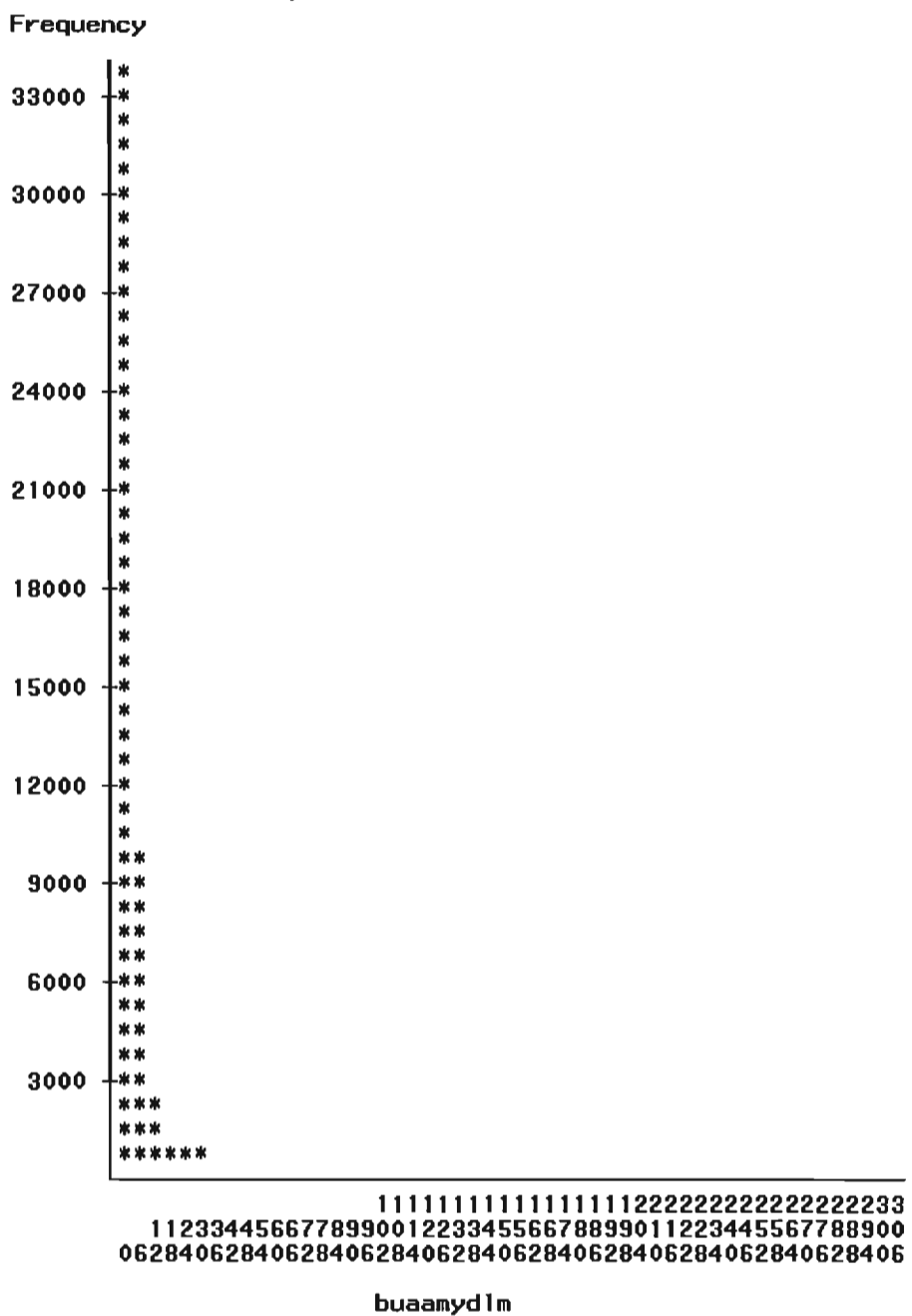
Variable Full Name: Box Forward Y Acceleration at Absolute Maximum Y-axis
Dynamic Moment (m/s^2)
Abbreviated Name: bfaamydlm



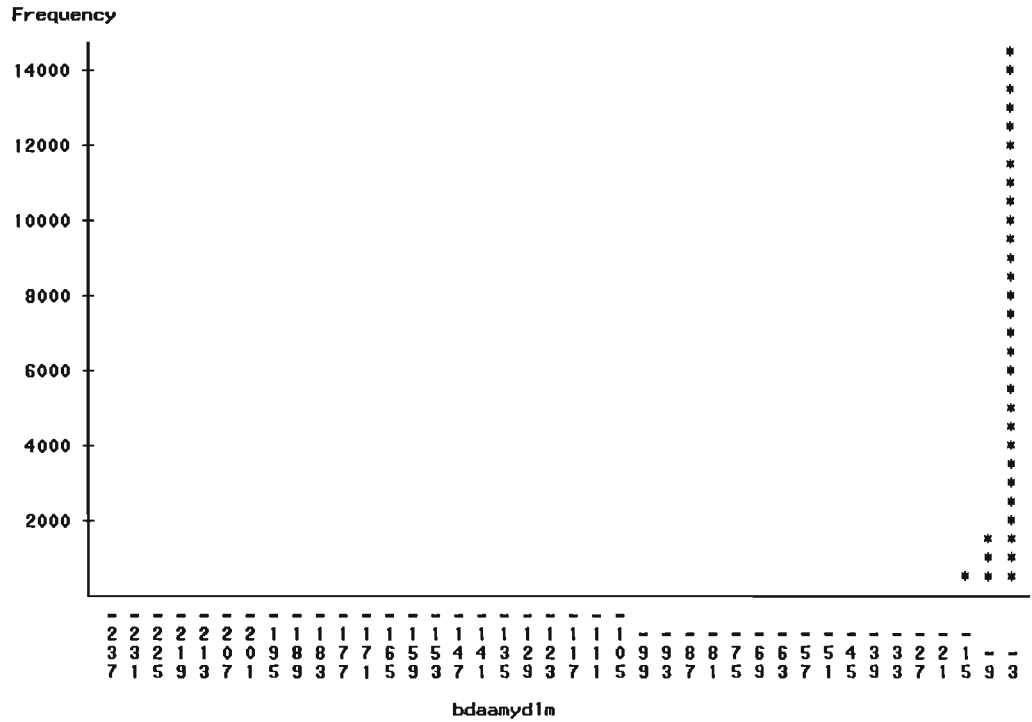
Variable Full Name: Box Backward Y Acceleration at Absolute Maximum Y-axis
Dynamic Moment (m/s^2)
Abbreviated Name: bbaamyd1m



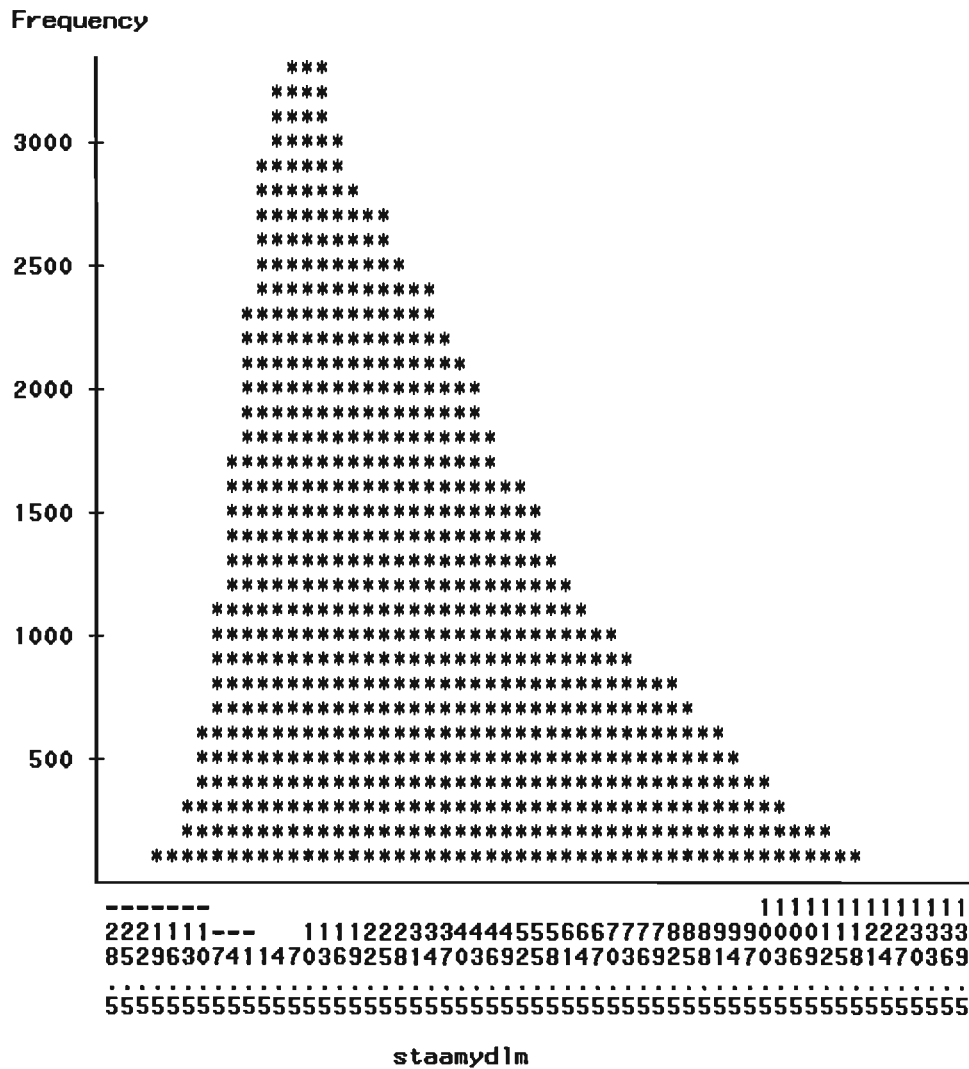
Variable Full Name: Box Up Z Acceleration at Absolute Maximum Y-axis Dynamic
Moment (m/s^2)
Abbreviated Name: buaamyd1m



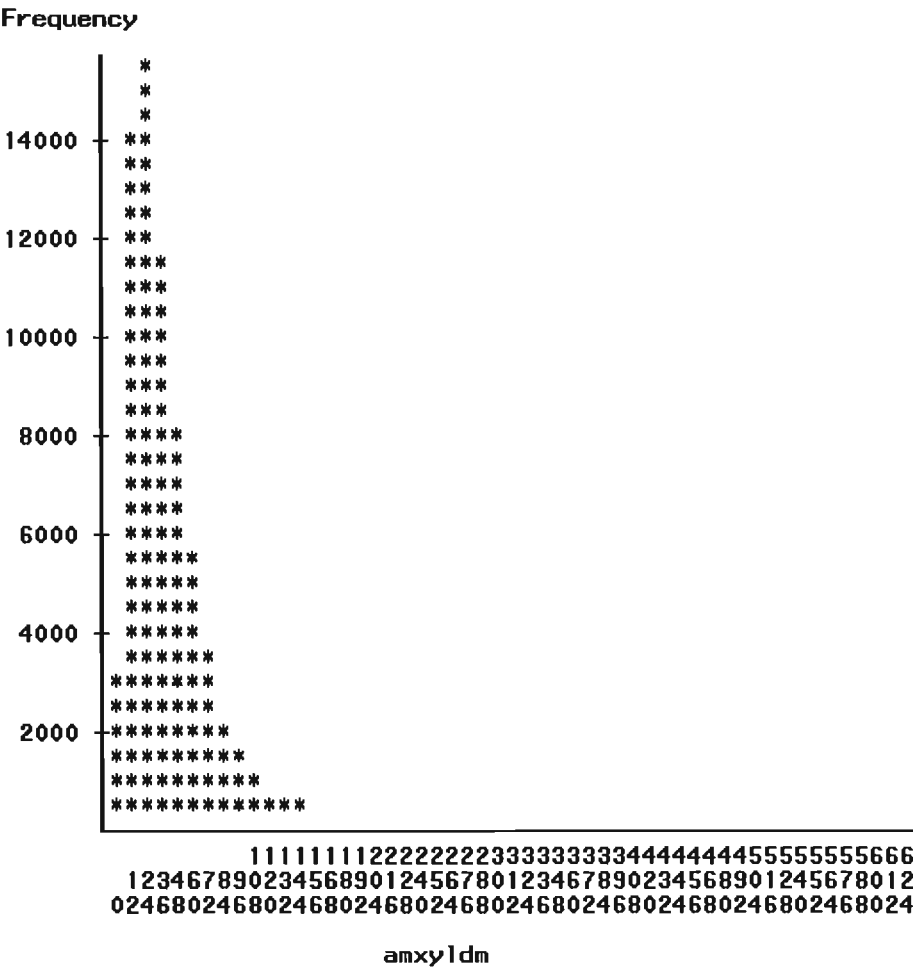
Variable Full Name: Box Down Z Acceleration at Absolute Maximum Y-axis Dynamic
Moment (m/s^2)
Abbreviated Name: bdaamyd1m



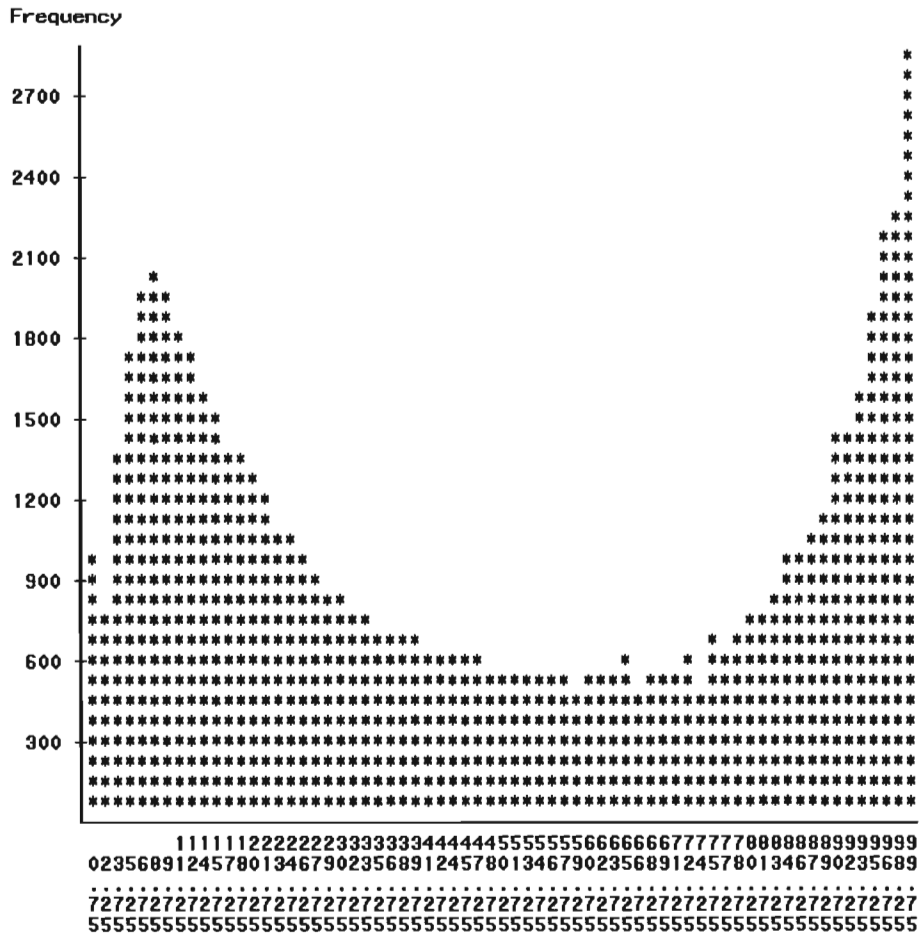
Variable Full Name: Sagittal Trunk Angle at Absolute Maximum Y-axis Dynamic Lift
Moment (Degrees)
Abbreviated Name: staamydlm



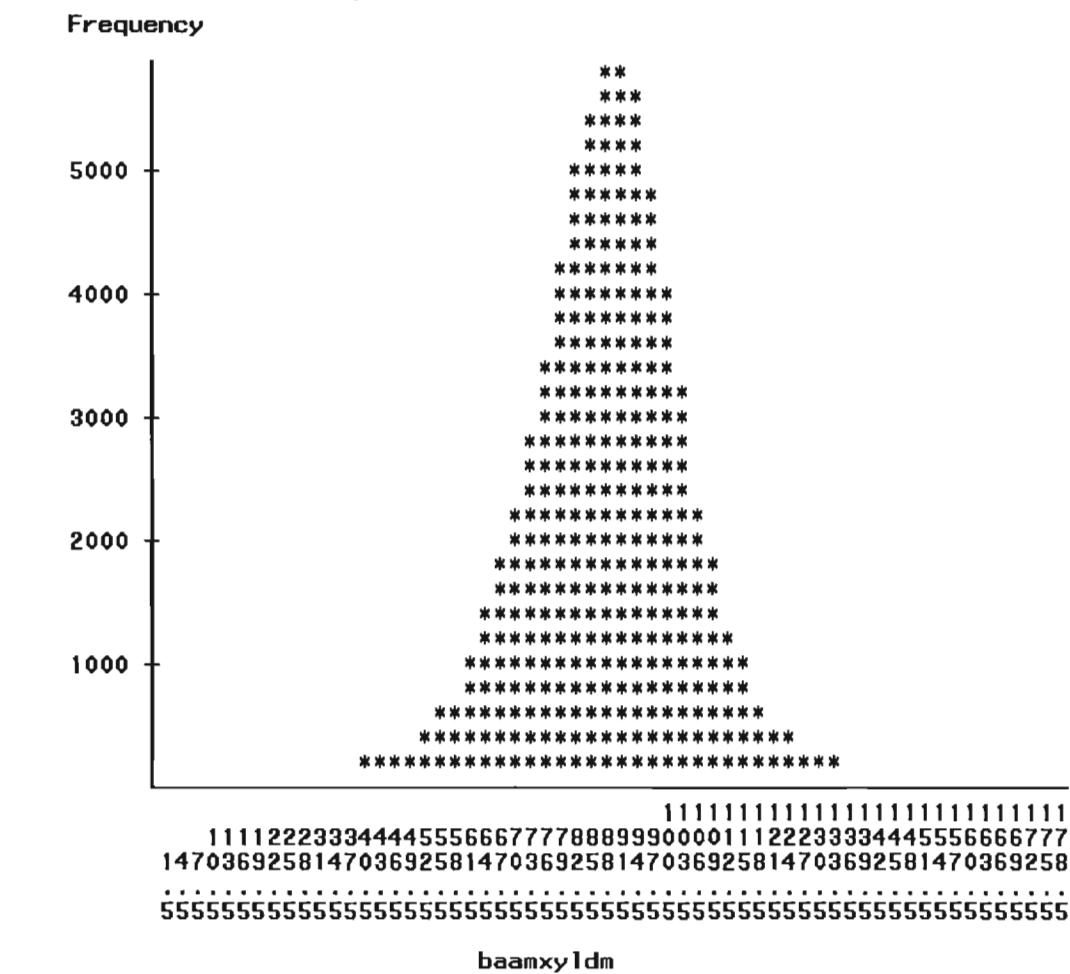
Variable Full Name: Absolute Maximum XY*Lift Dynamic Moment (N*m)
Abbreviated Name: amxyldm



Variable Full Name: Percent Time of Absolute Maximum XY*Lift Dynamic Moment
(%)
Abbreviated Name: ptamxyldm



Variable Full Name: Box Asymmetry at Absolute Maximum XY*Lift Dynamic
Moment (Degrees)
Abbreviated Name: baamxyldm



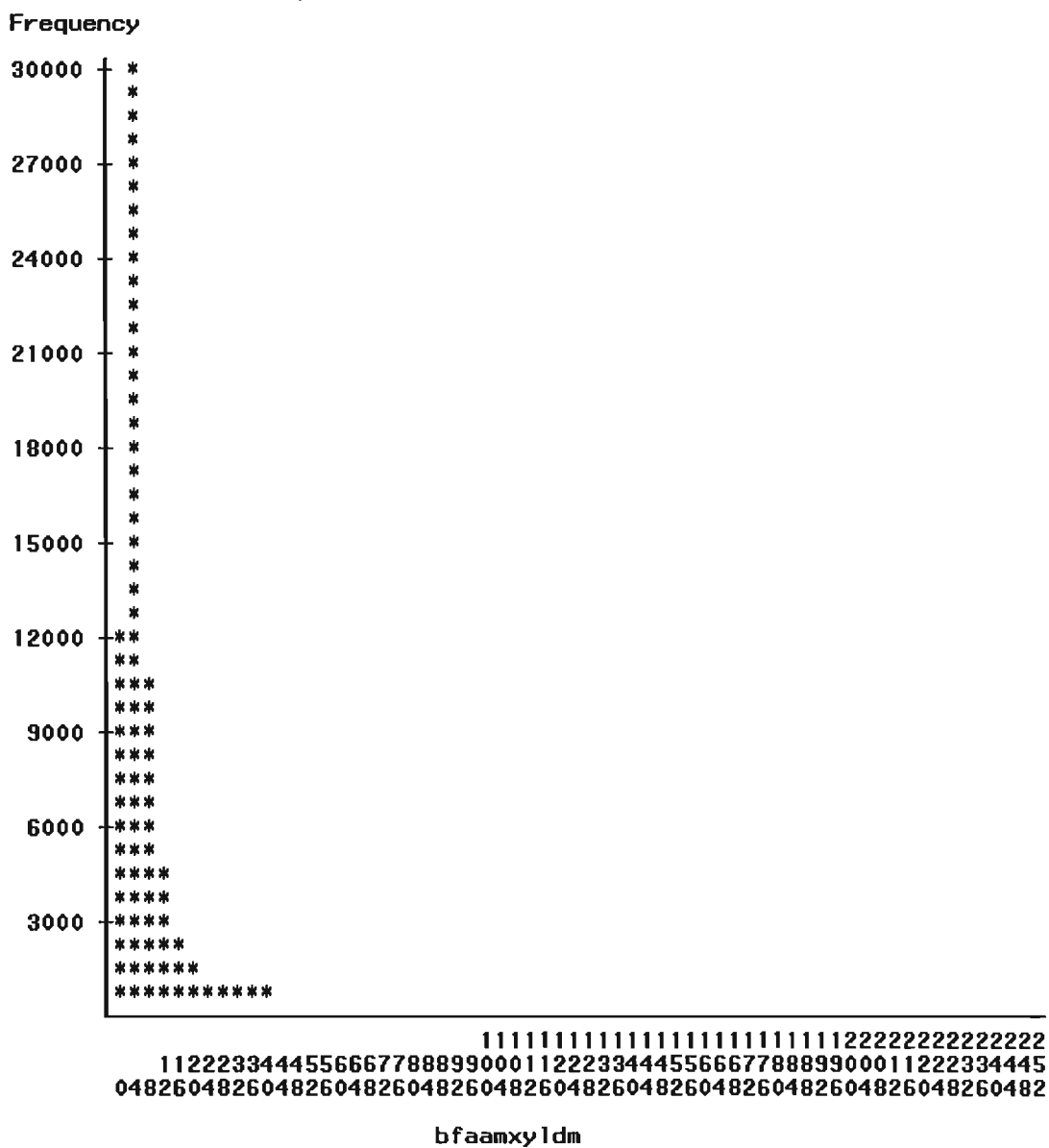
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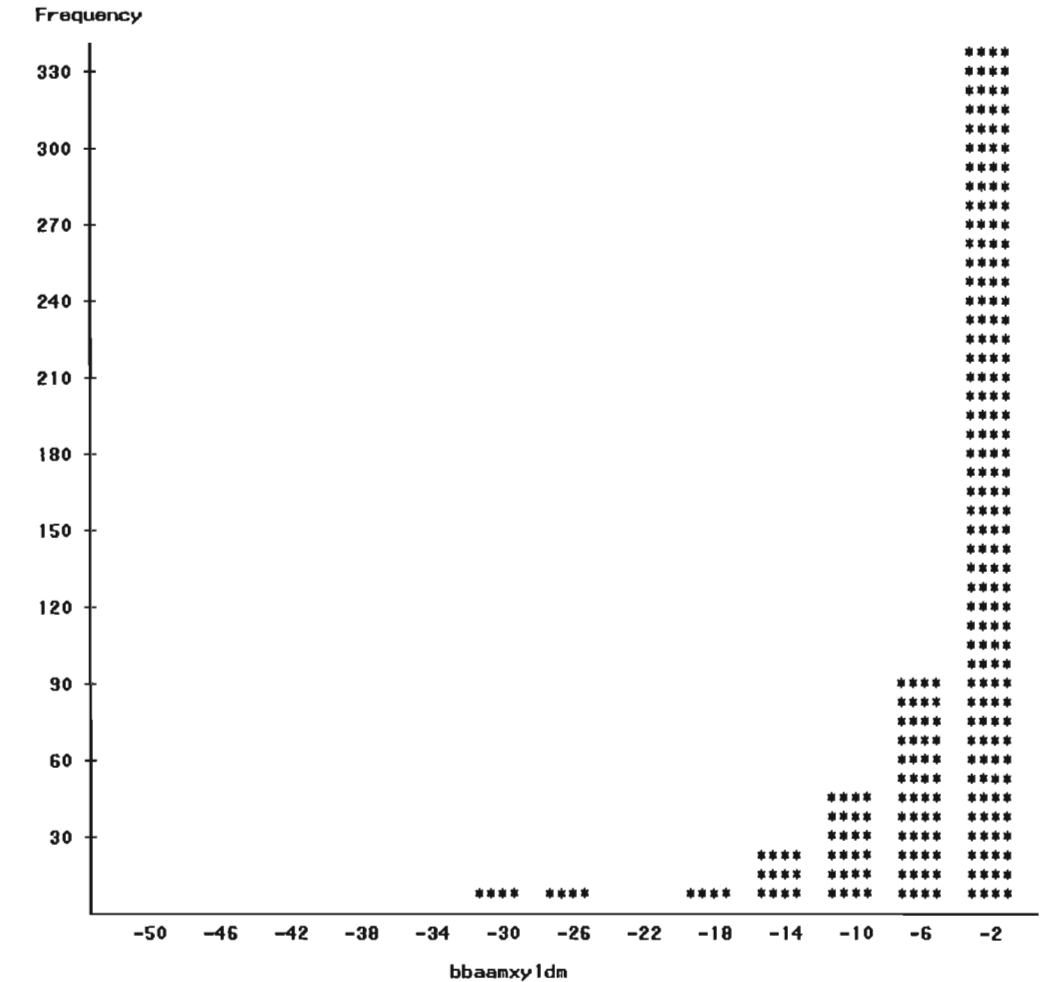
Frequency



Variable Full Name: Box Forward Y Acceleration at Absolute Maximum XY*Lift
Dynamic Moment (m/s^2)
Abbreviated Name: bfaamxyldm



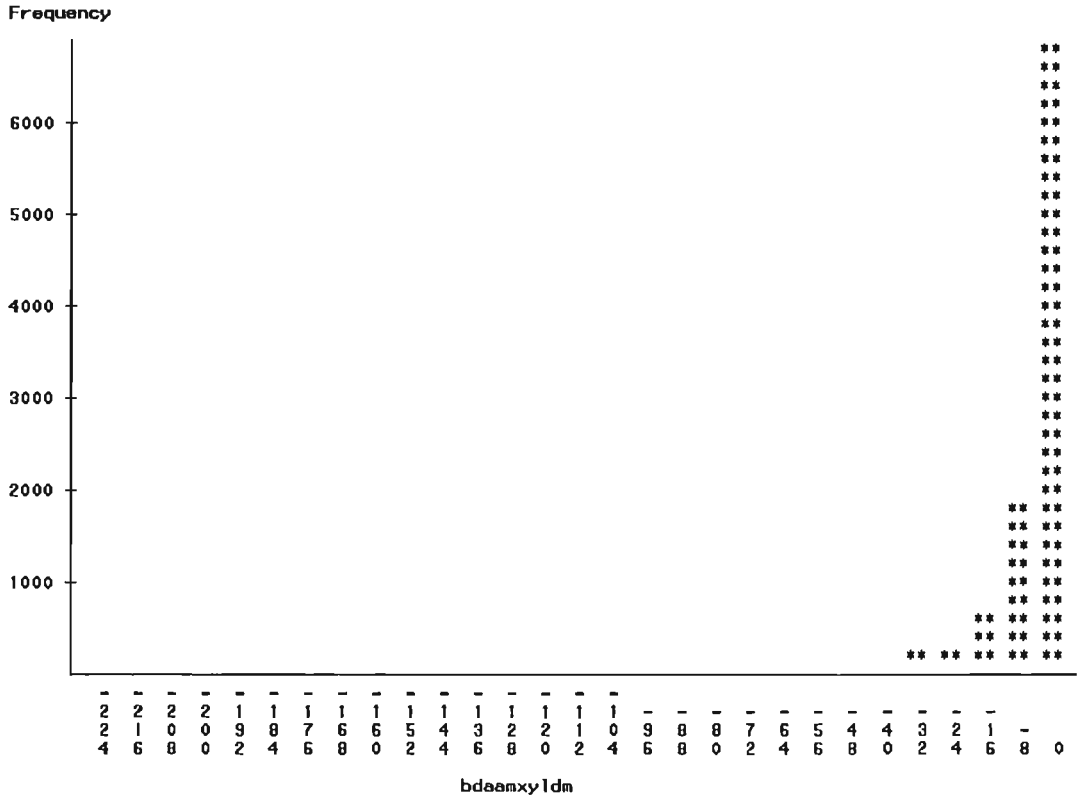
Variable Full Name: Box Backward Y Acceleration at Absolute Maximum XY*Lift
Dynamic Moment (m/s^2)
Abbreviated Name: bbaamxyldm



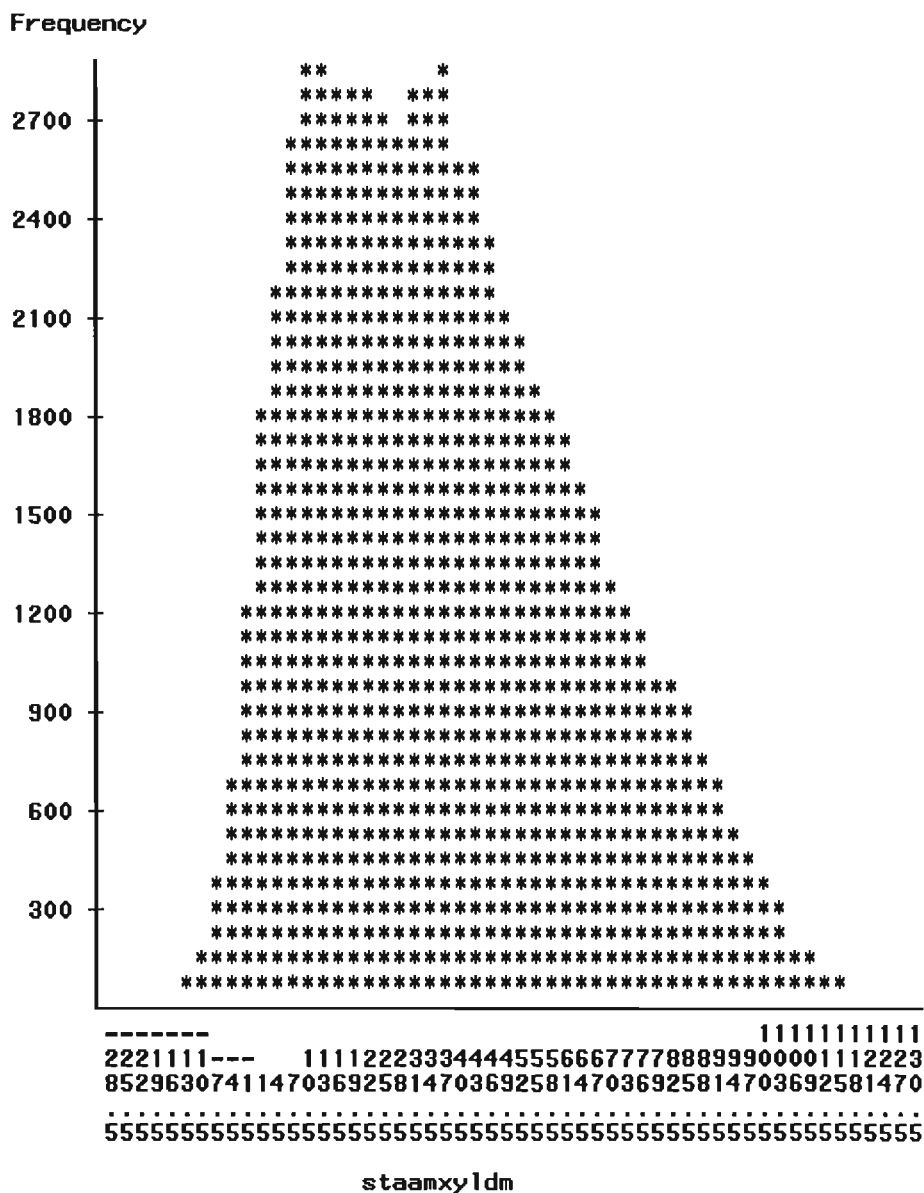
Abbreviated Name: buaamxyldm



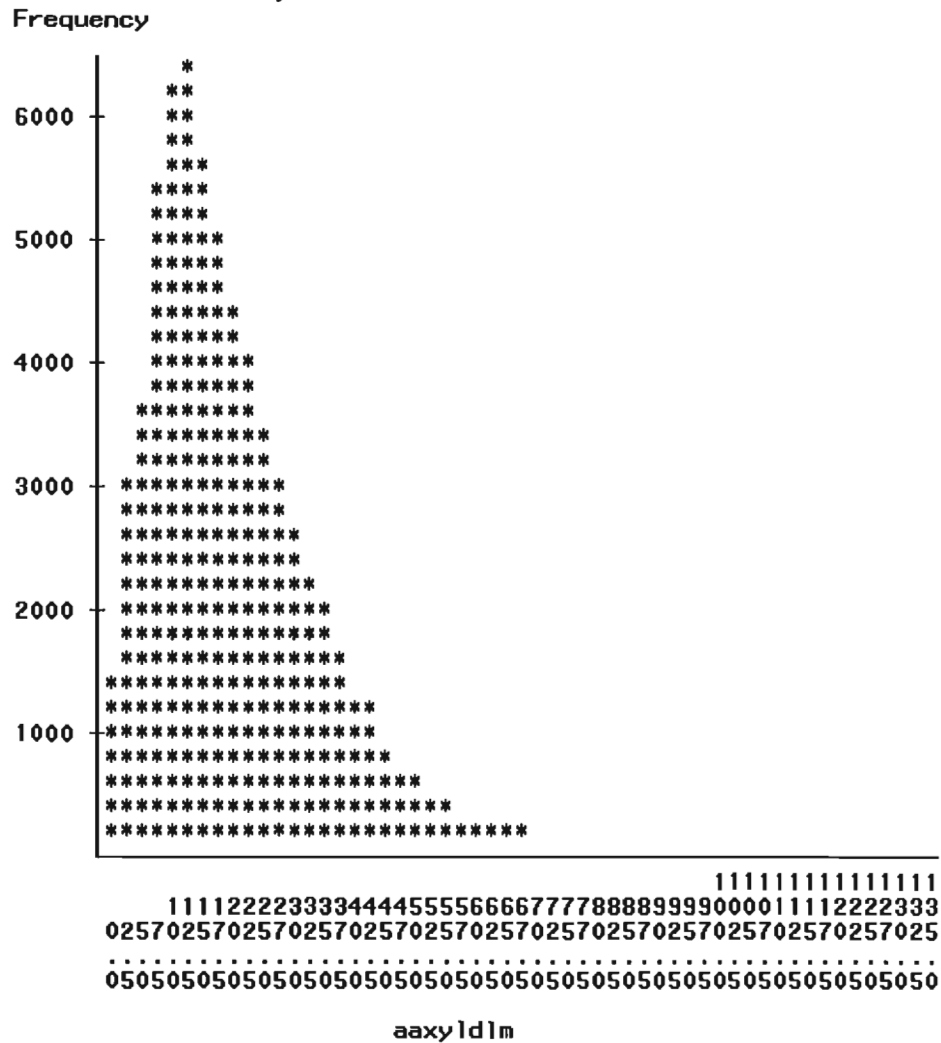
Variable Full Name: Box Down Z Acceleration at Absolute Maximum XY*Lift
Dynamic Moment (m/s^2)
Abbreviated Name: bdaamxyldm



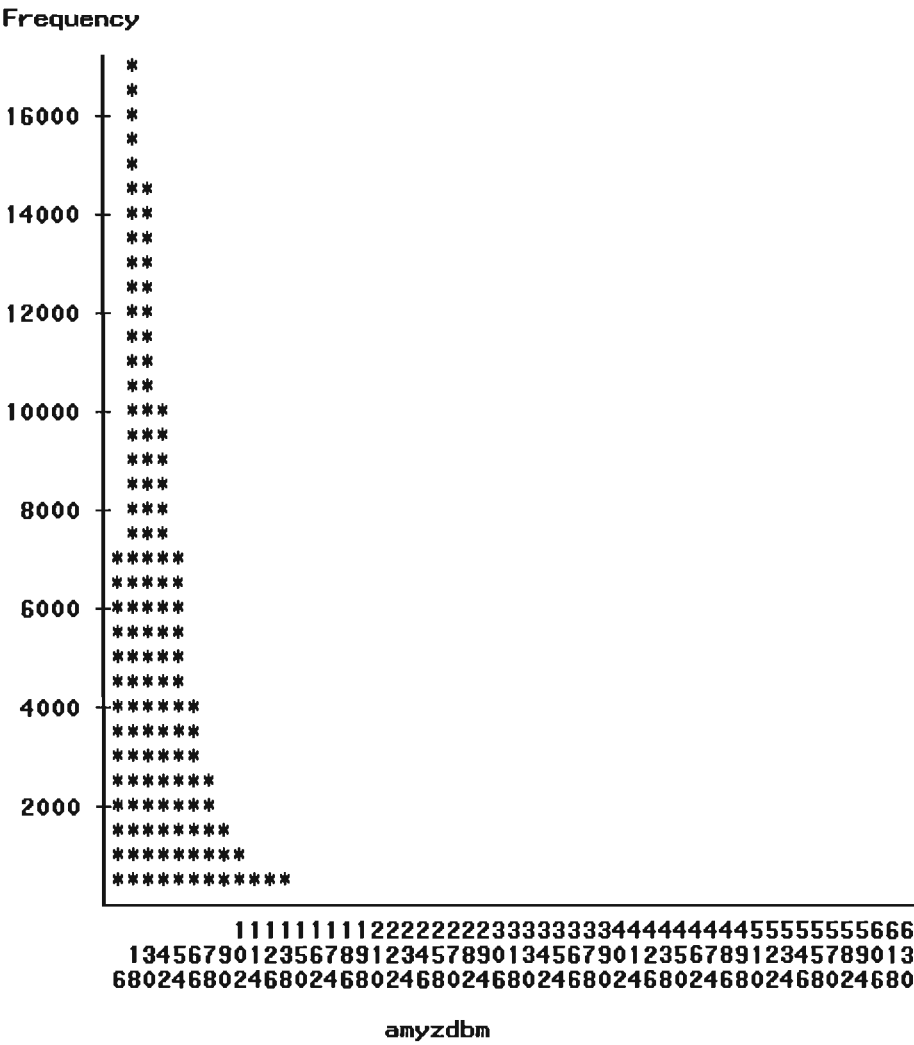
Variable Full Name: Sagittal Trunk Angle at Absolute Maximum XY*Lift Dynamic Moment (Degrees)
Abbreviated Name: staamxyldm



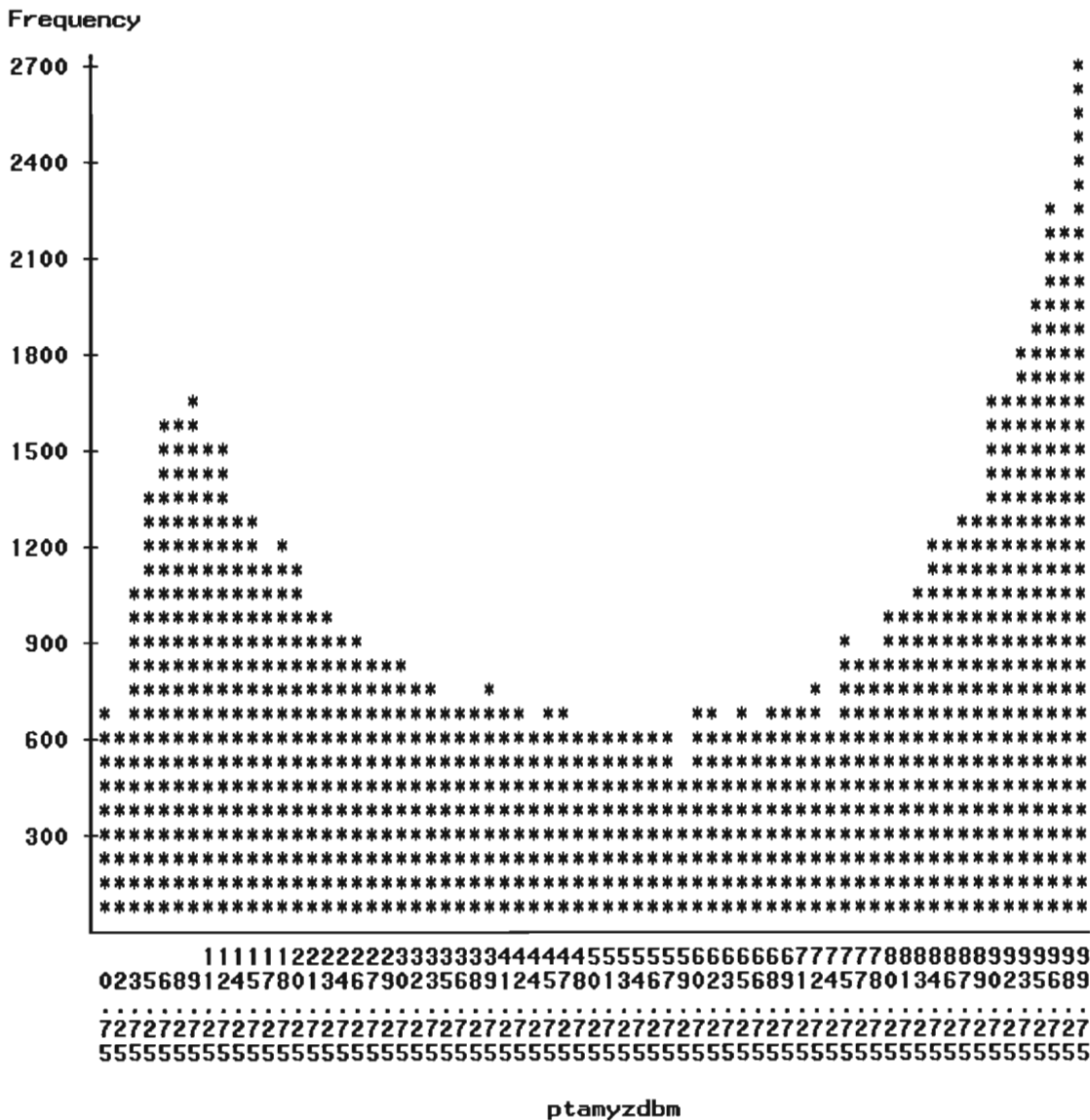
Abbreviated Name: aaxyldlm



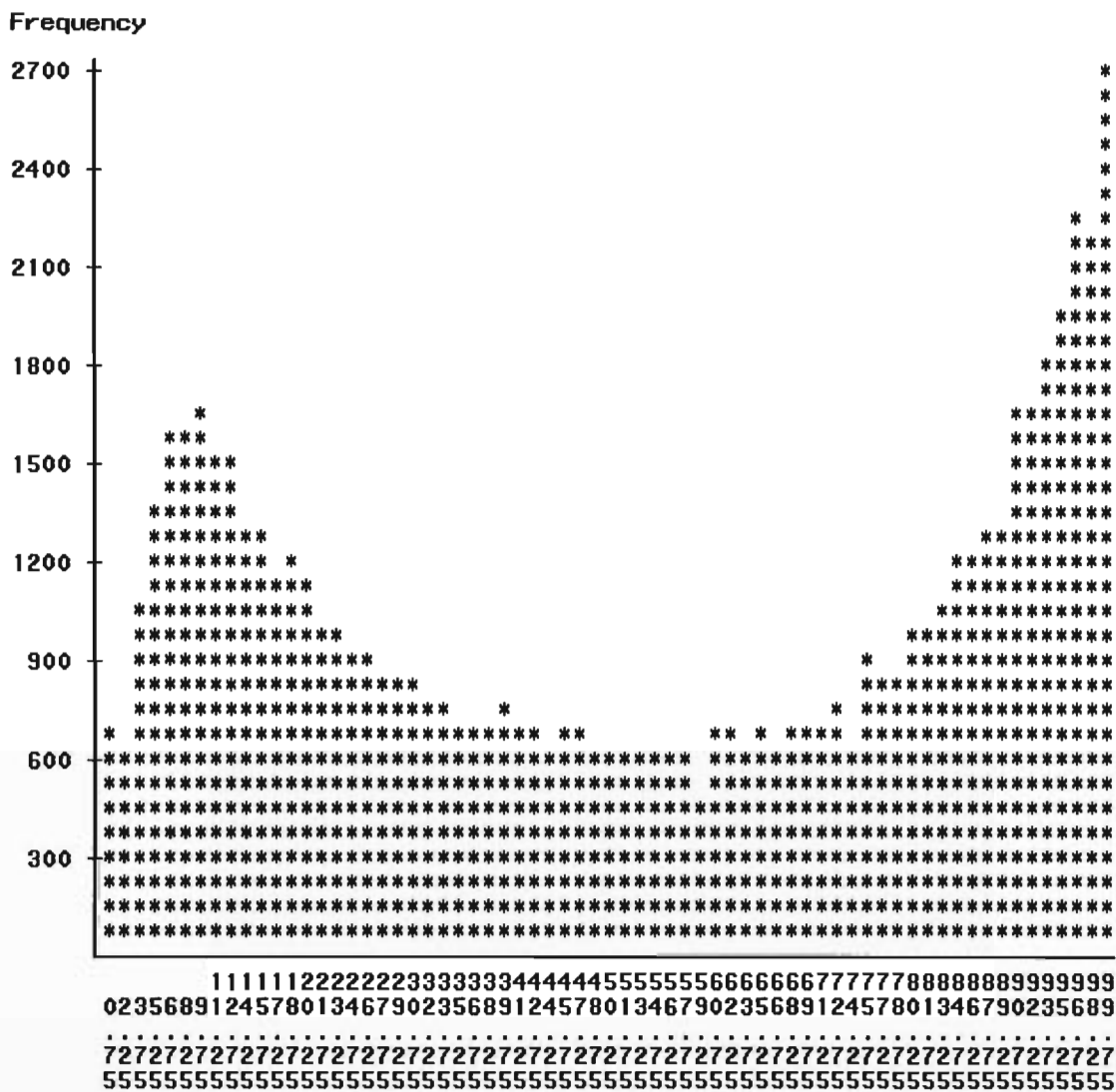
Variable Full Name: Absolute Maximum Total Dynamic Sagittal Moment (N*m)
Abbreviated Name: amyzdbm



Variable Full Name: Percent Time of Absolute Maximum Total Dynamic Sagittal
Moment (%)
Abbreviated Name: ptamyzdbm

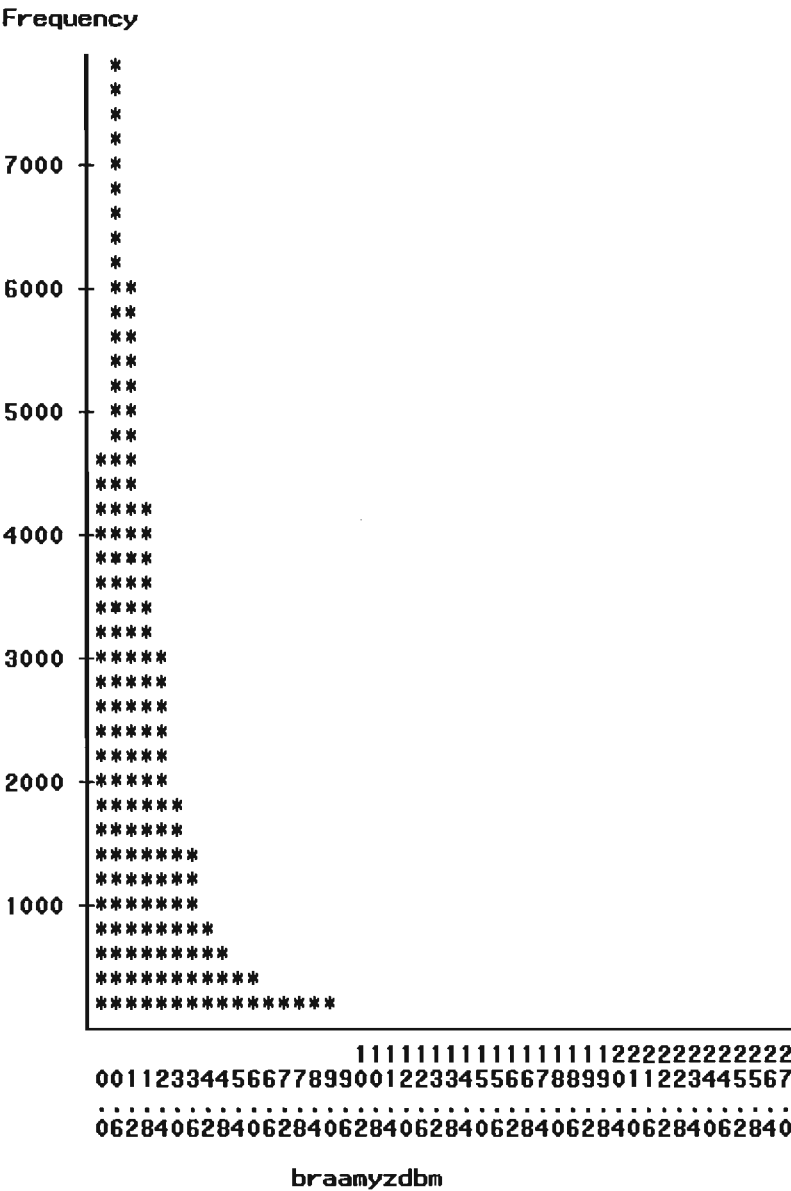


Variable Full Name: Box Asymmetry at Absolute Maximum Total Dynamic Sagittal Moment (Degrees)
Abbreviated Name: baamyzdbm

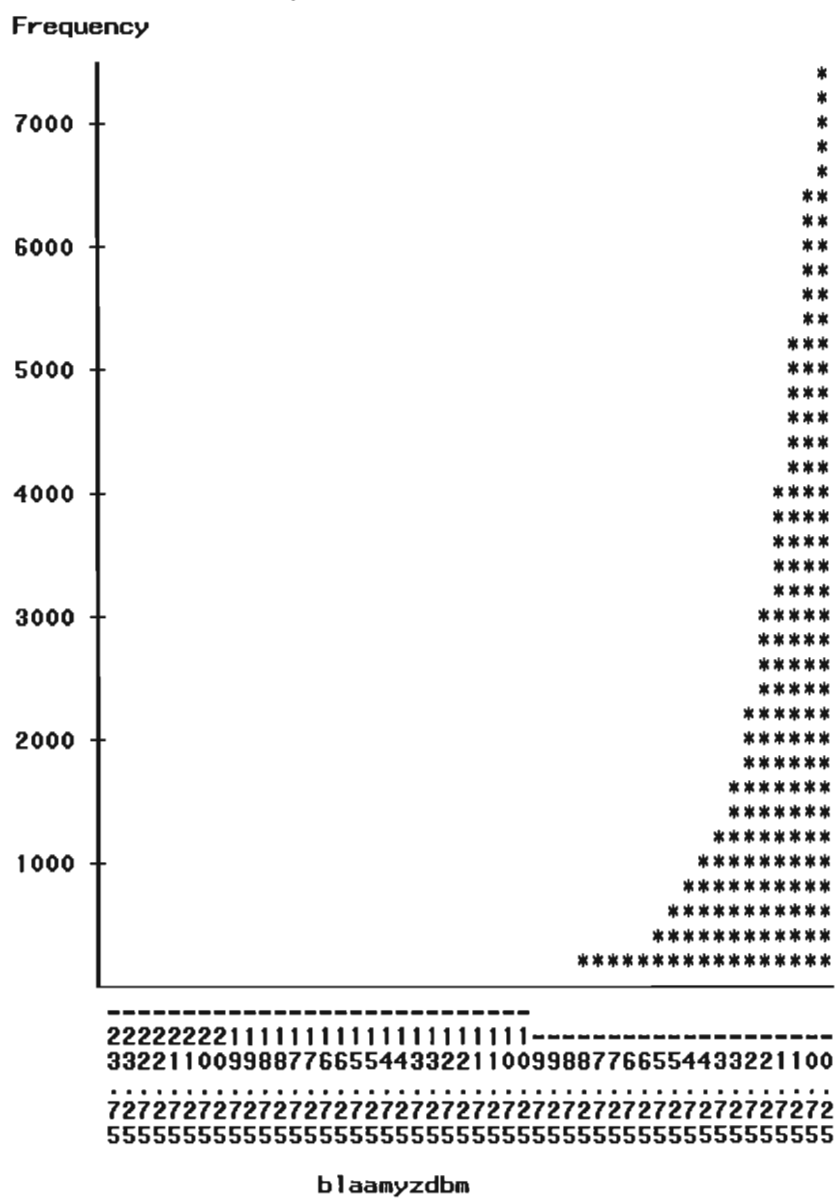


ptamyzdbm

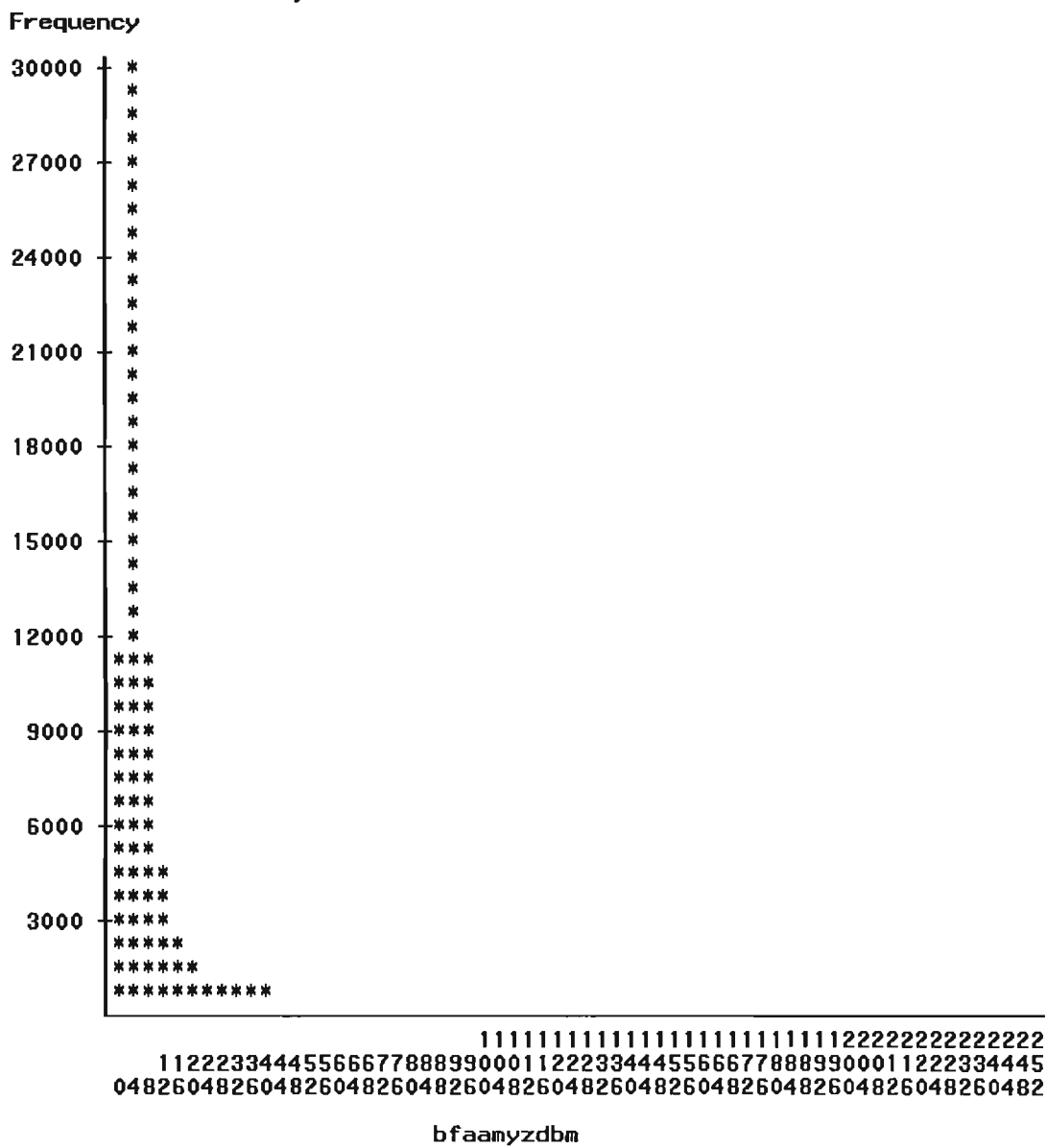
Variable Full Name: Box Rightward X Acceleration at Absolute Maximum Total
Dynamic Sagittal Moment (m/s^2)
Abbreviated Name: braamyzdbm



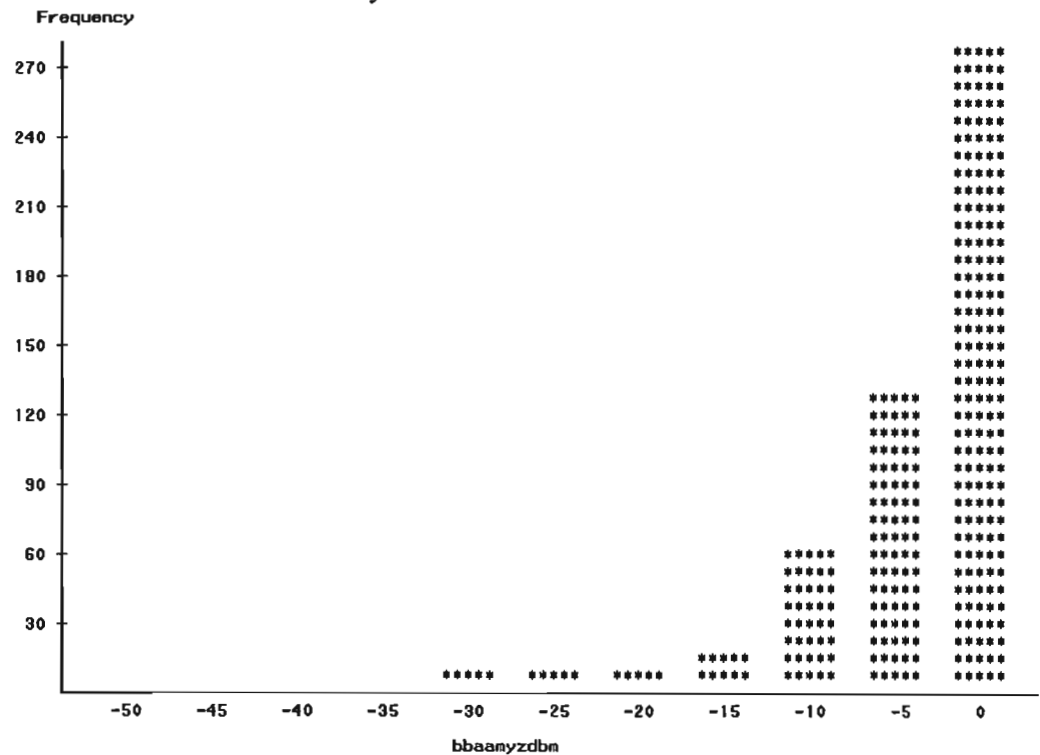
Variable Full Name: Box Leftward X Acceleration at Absolute Maximum Total Dynamic Sagittal Moment (m/s²)
Abbreviated Name: blaamyzdbm



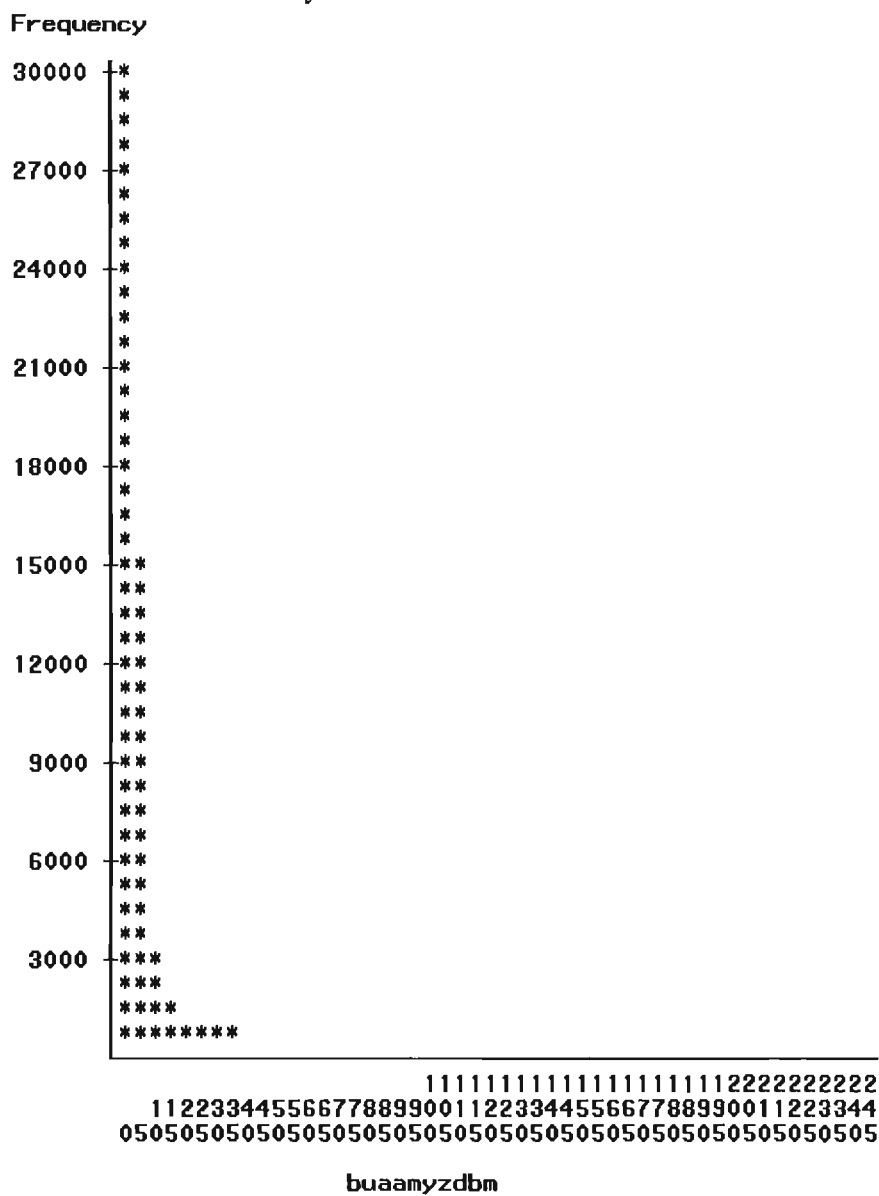
Variable Full Name: Box Forward Y Acceleration at Absolute Maximum Total Dynamic Sagittal Moment (m/s^2)
Abbreviated Name: bfaamyzdbm



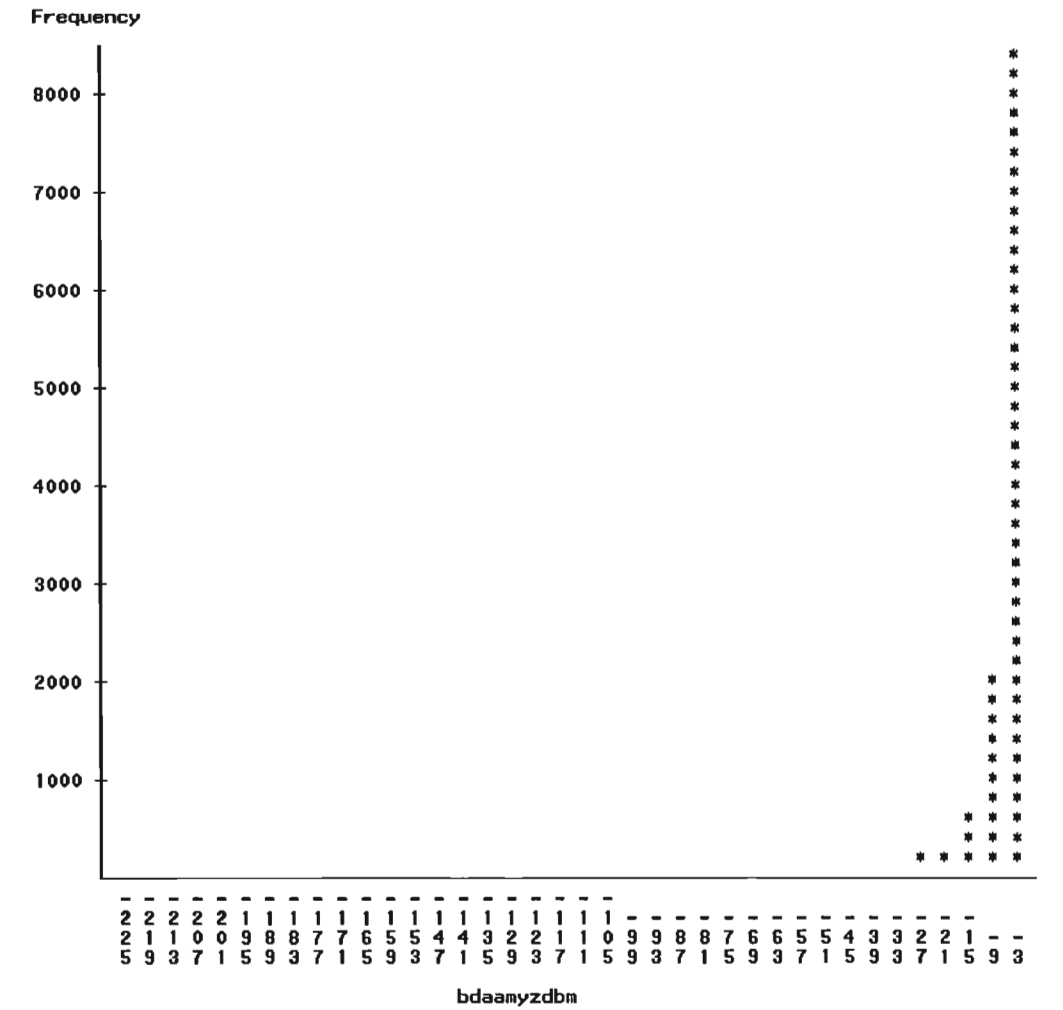
Variable Full Name: Box Backward Y Acceleration at Absolute Maximum Total
Dynamic Sagittal Moment (m/s^2)
Abbreviated Name: bbaamyzdbm



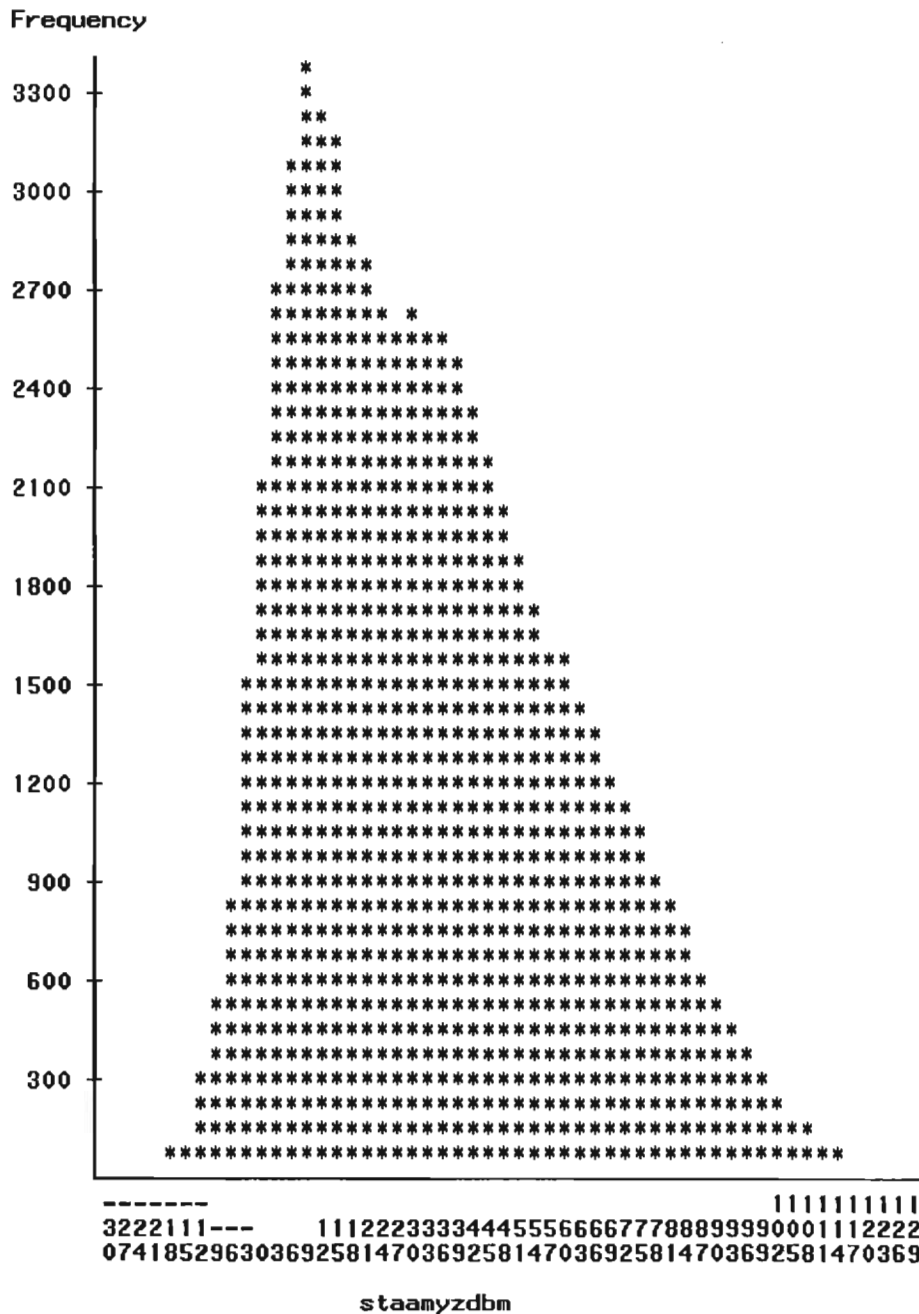
Variable Full Name: Box Up Z Acceleration at Absolute Maximum Total Dynamic Sagittal Moment (m/s^2)
Abbreviated Name: buaamyzdbm



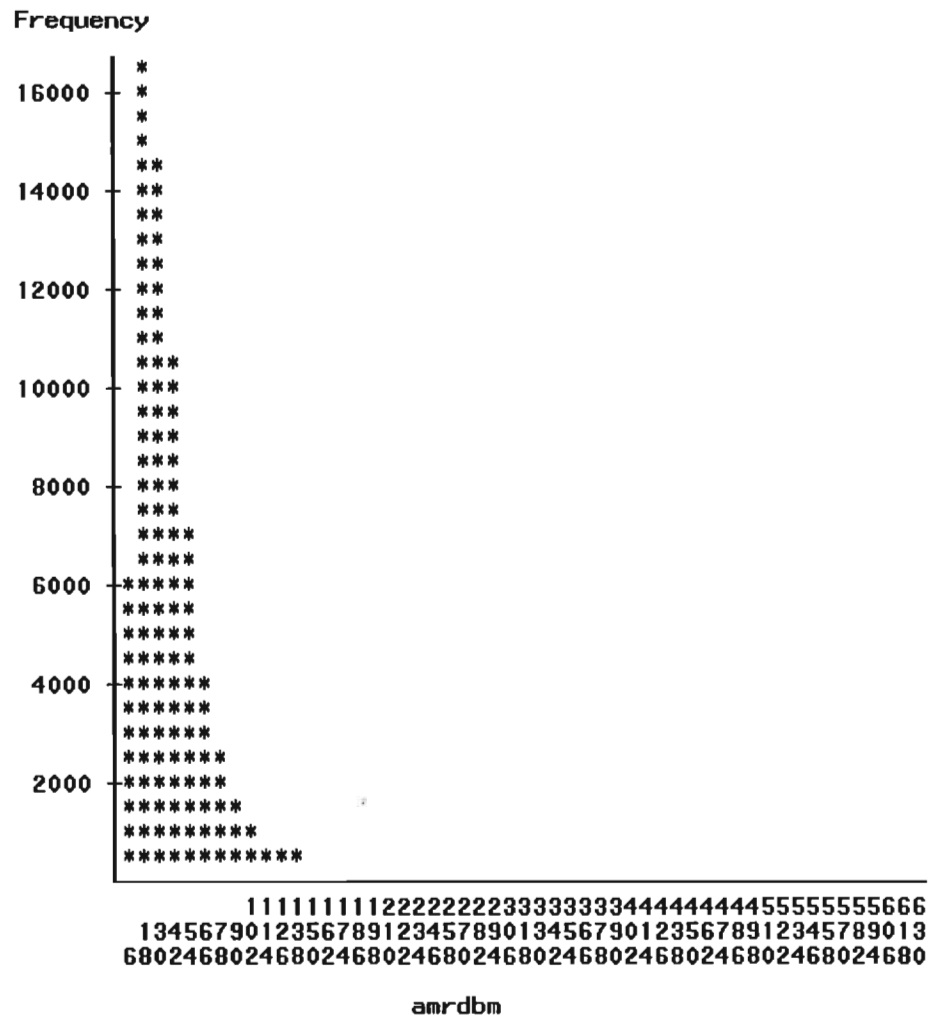
Variable Full Name: Box Down Z Acceleration at Absolute Maximum Total Dynamic
Sagittal Moment (m/s^2)
Abbreviated Name: bdaamyzdbm



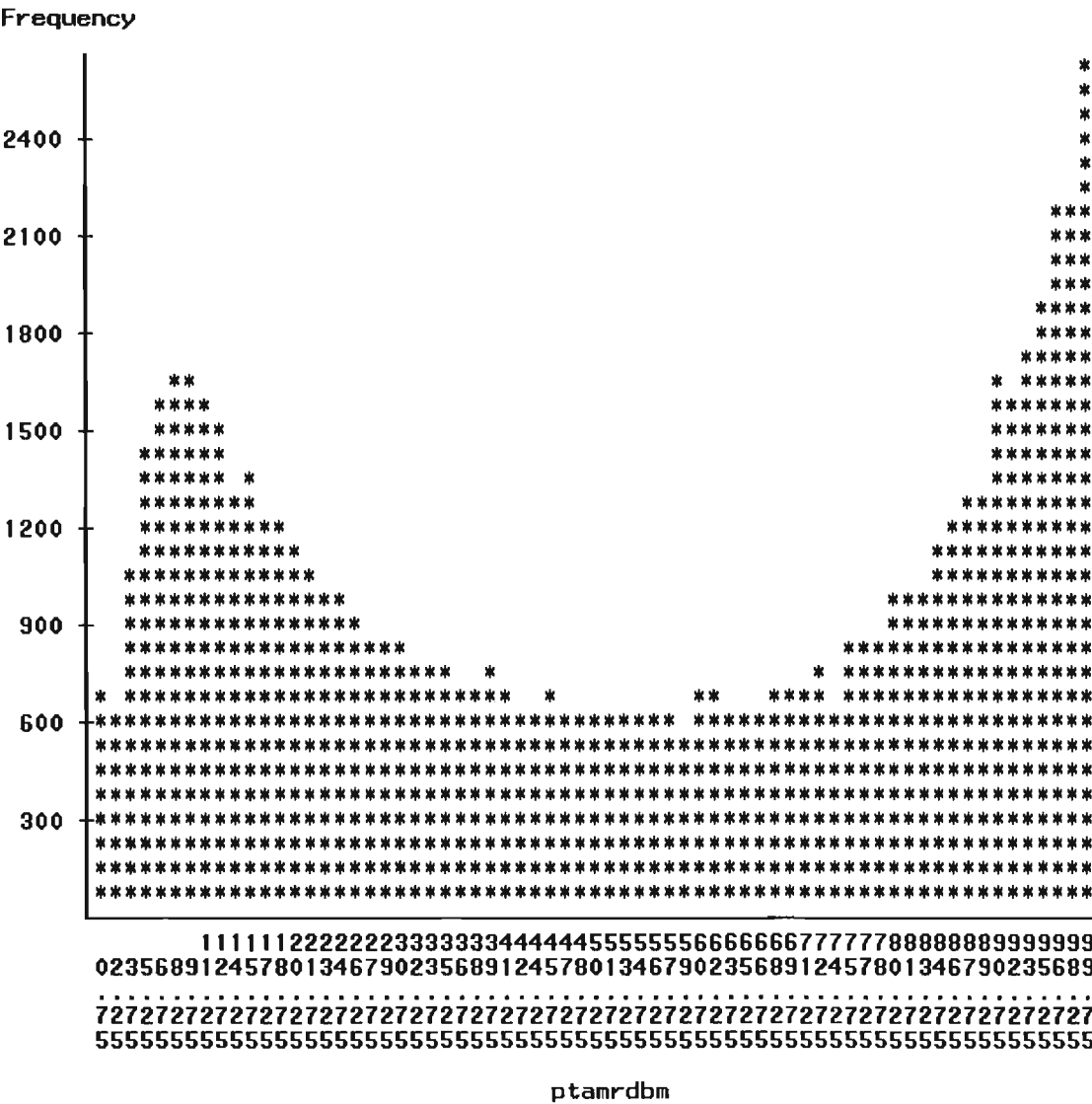
Variable Full Name: Sagittal Trunk Angle at Absolute Maximum Total Dynamic
 Sagittal Moment (Degrees)
 Abbreviated Name: staamyzdbm



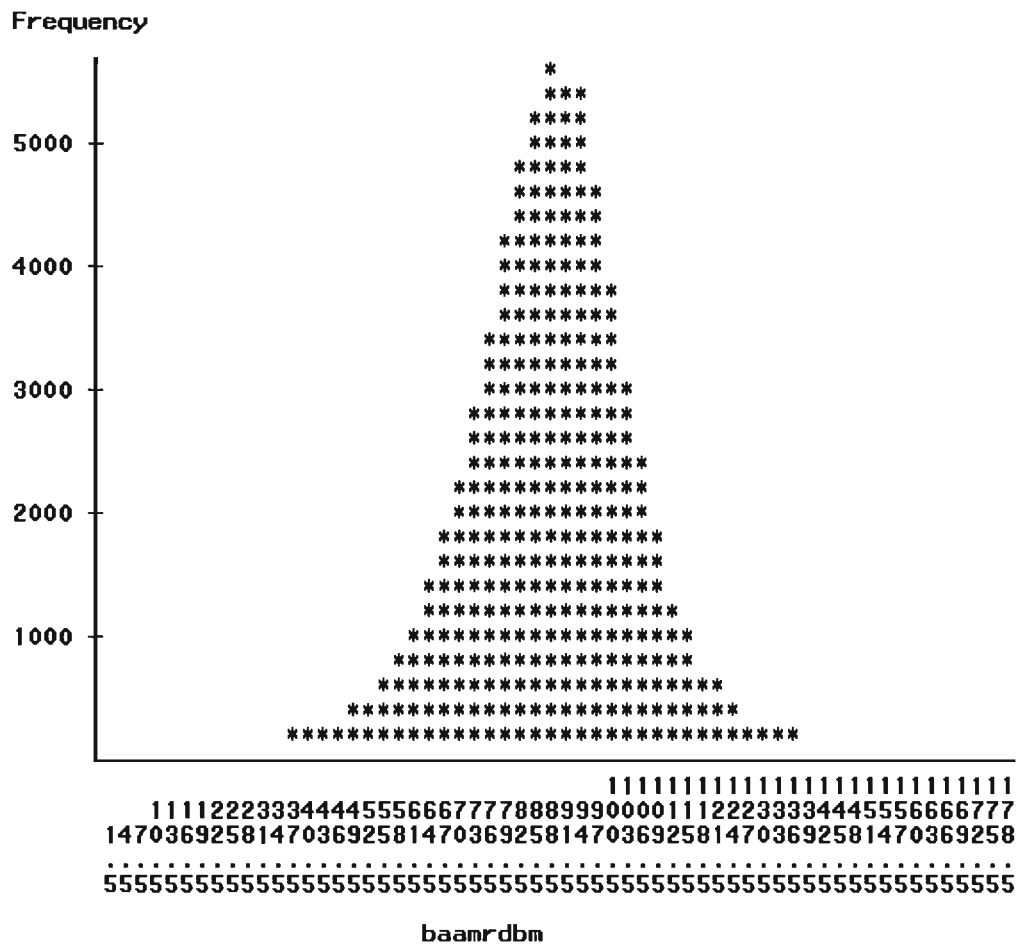
Variable Full Name: Absolute Maximum Resultant Dynamic Moment (N*m)
Abbreviated Name: amrdbm



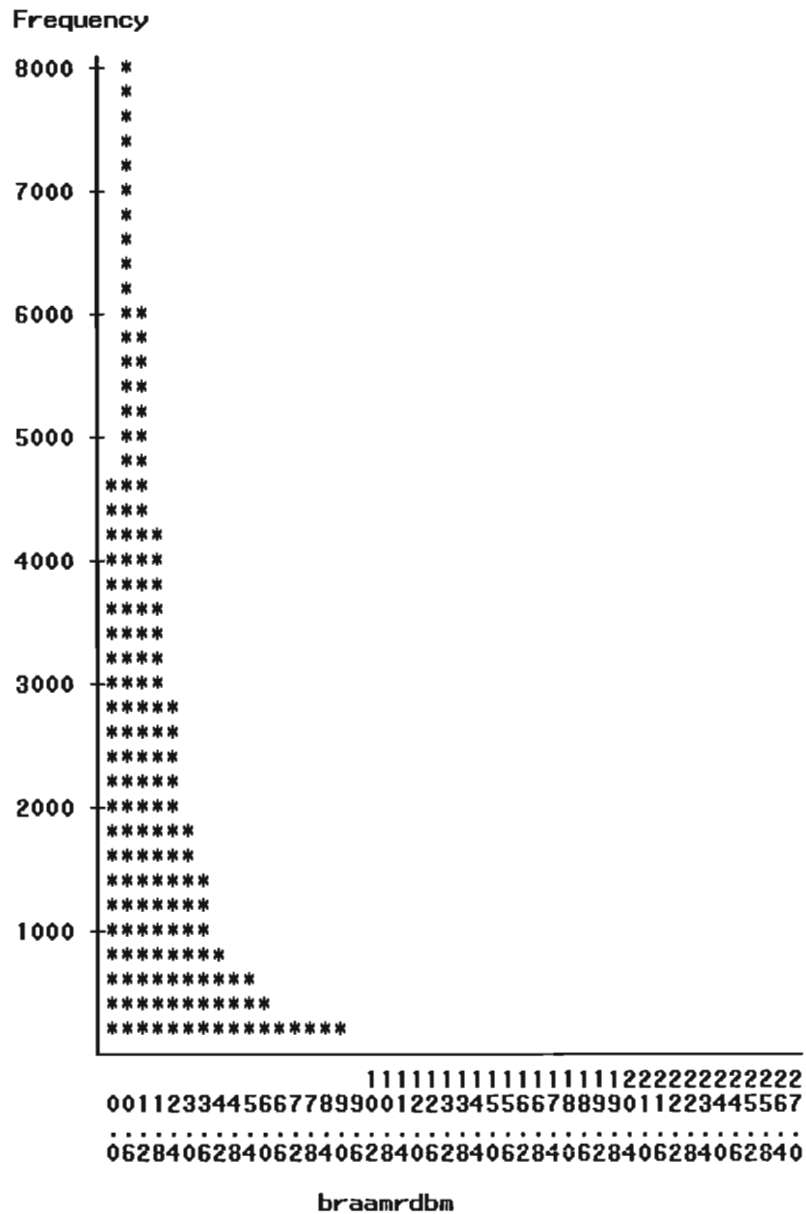
Variable Full Name: Percent Time of Absolute Maximum Resultant Dynamic Moment (%)
Abbreviated Name: ptamrdbm



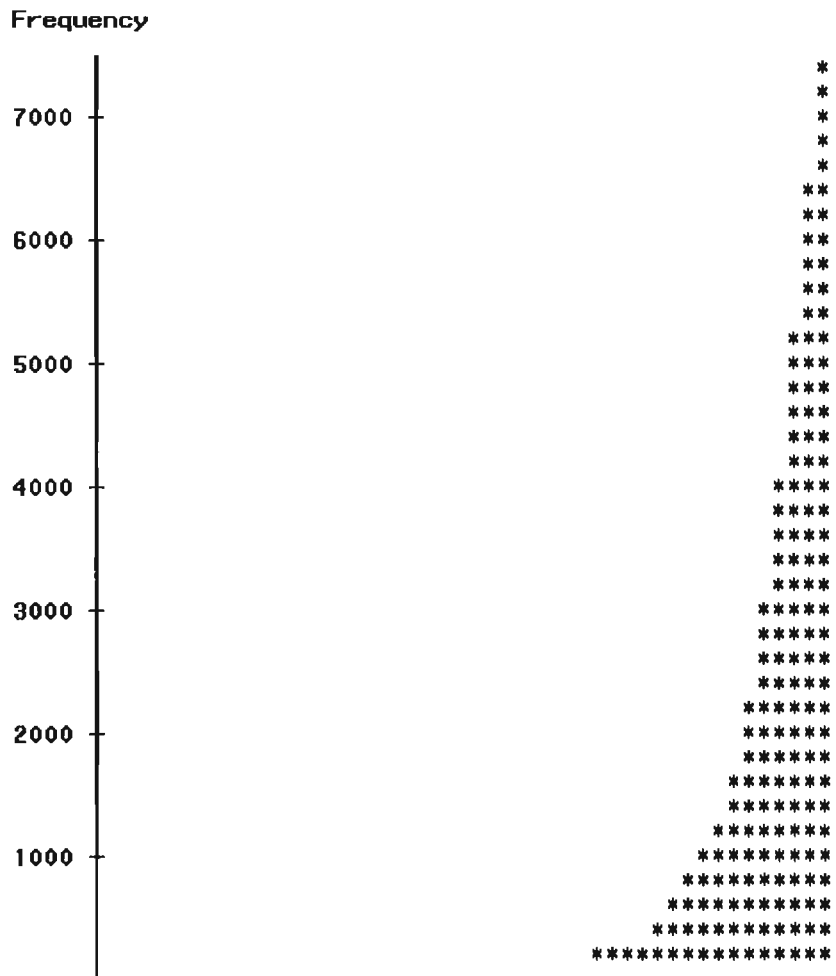
Variable Full Name: Box Asymmetry at Absolute Maximum Resultant Dynamic Moment (Degrees)
Abbreviated Name: baamrdbm



Variable Full Name: Box Rightward X Acceleration at Absolute Maximum Resultant
Dynamic Moment (m/s^2)
Abbreviated Name: braamrdbm

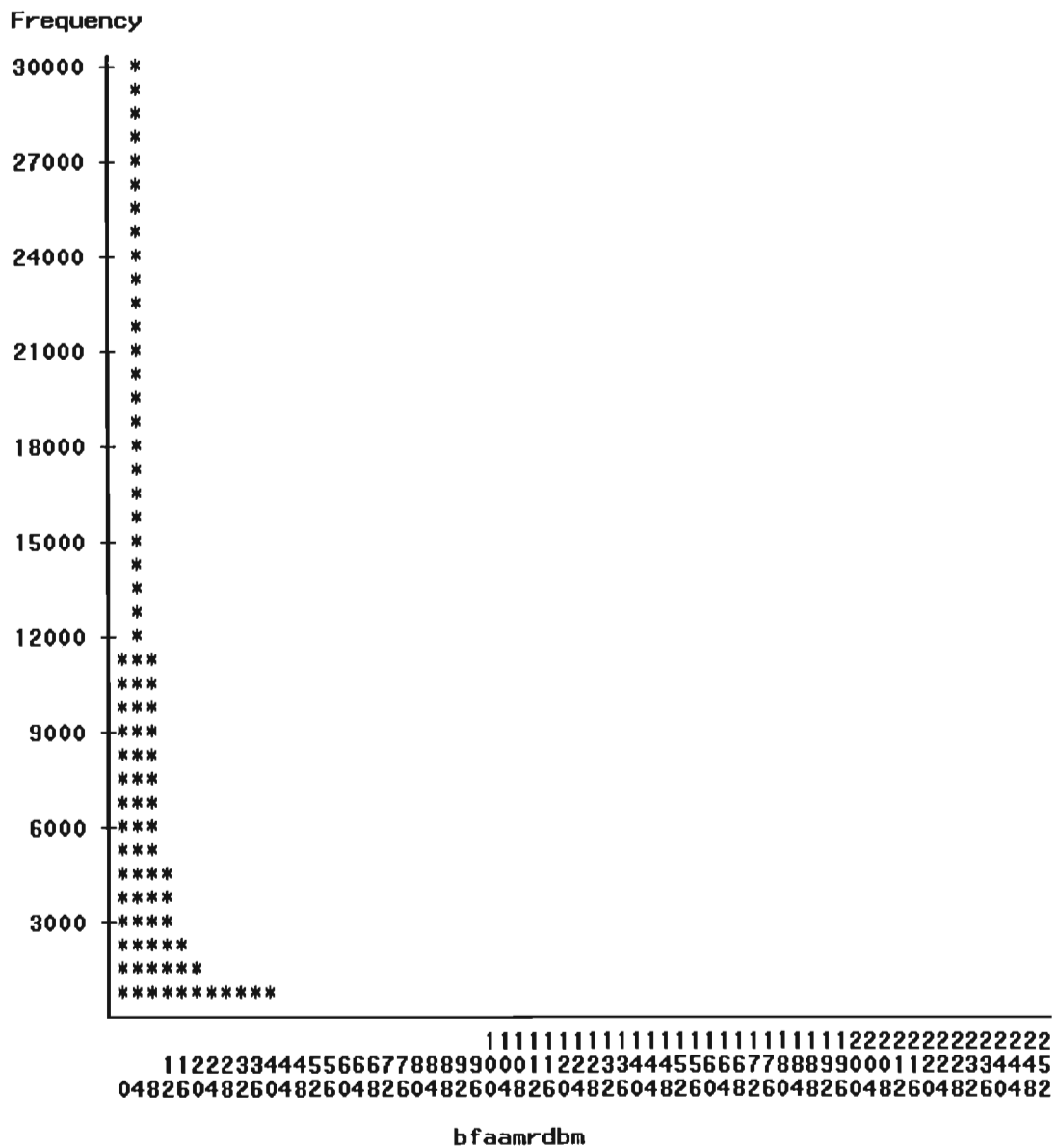


Variable Full Name: Box Leftward X Acceleration at Absolute Maximum Resultant Dynamic Moment (m/s²)
Abbreviated Name: blaamrdbm

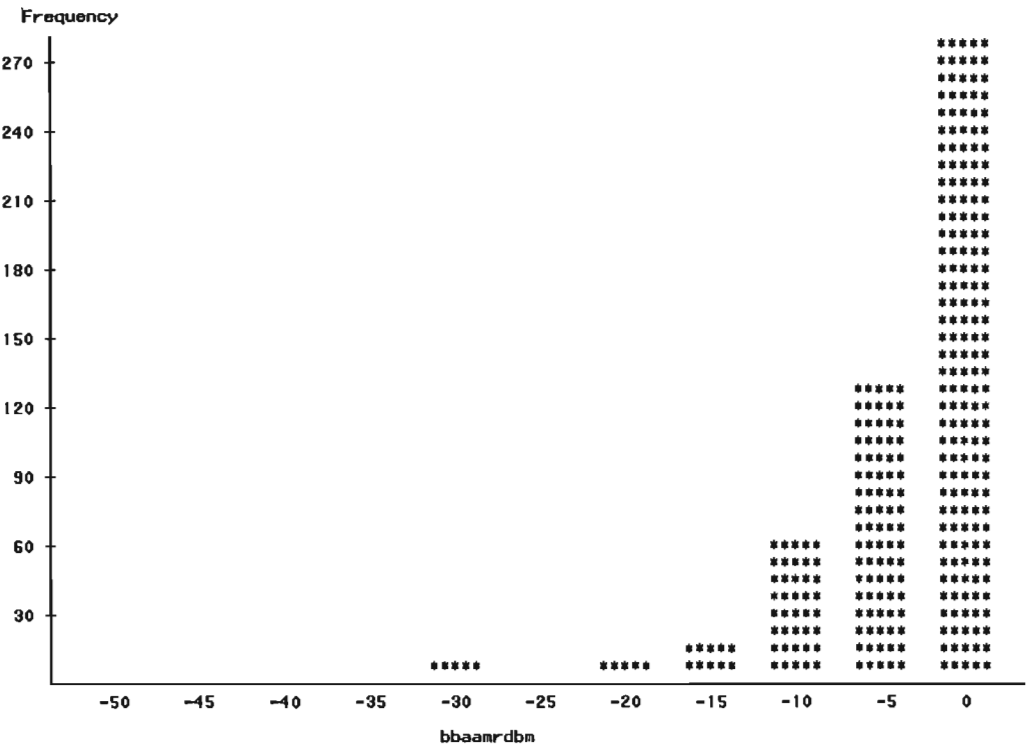
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b1aamrdbm

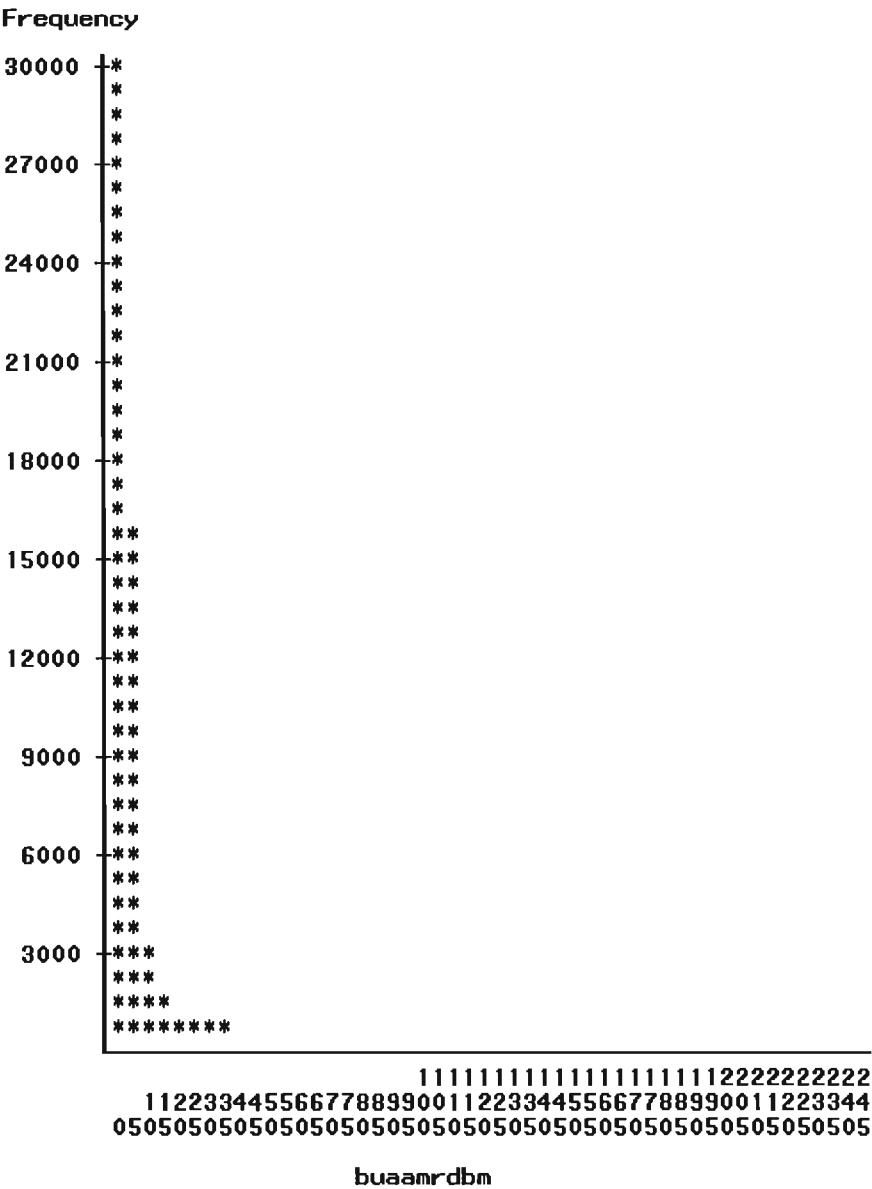
Variable Full Name: Box Forward Y Acceleration at Absolute Maximum Resultant Dynamic Moment (m/s^2)
Abbreviated Name: bfaamrdbm



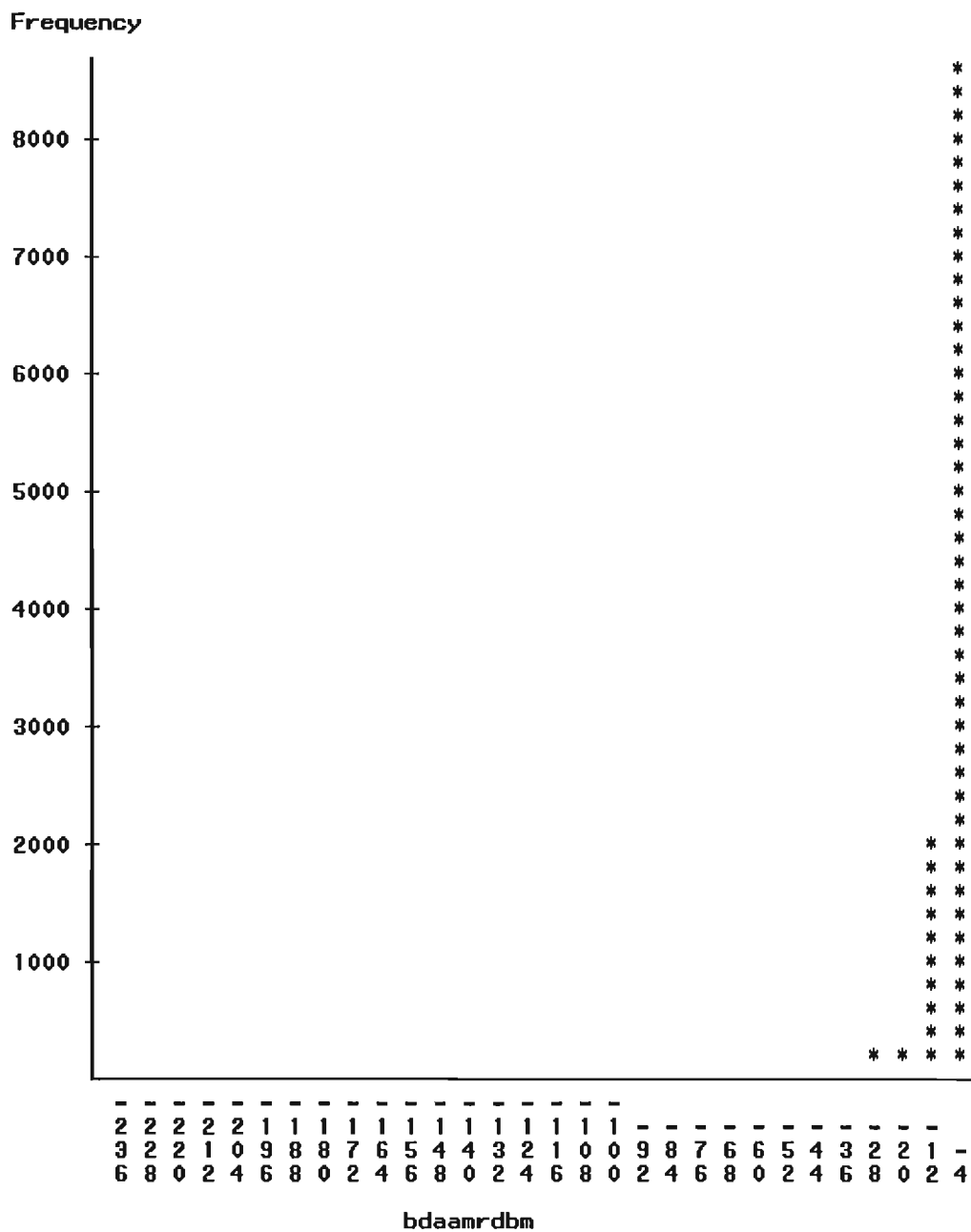
Variable Full Name: Box Backward Y Acceleration at Absolute Maximum Resultant
Dynamic Moment (m/s^2)
Abbreviated Name: bbaamrdbm



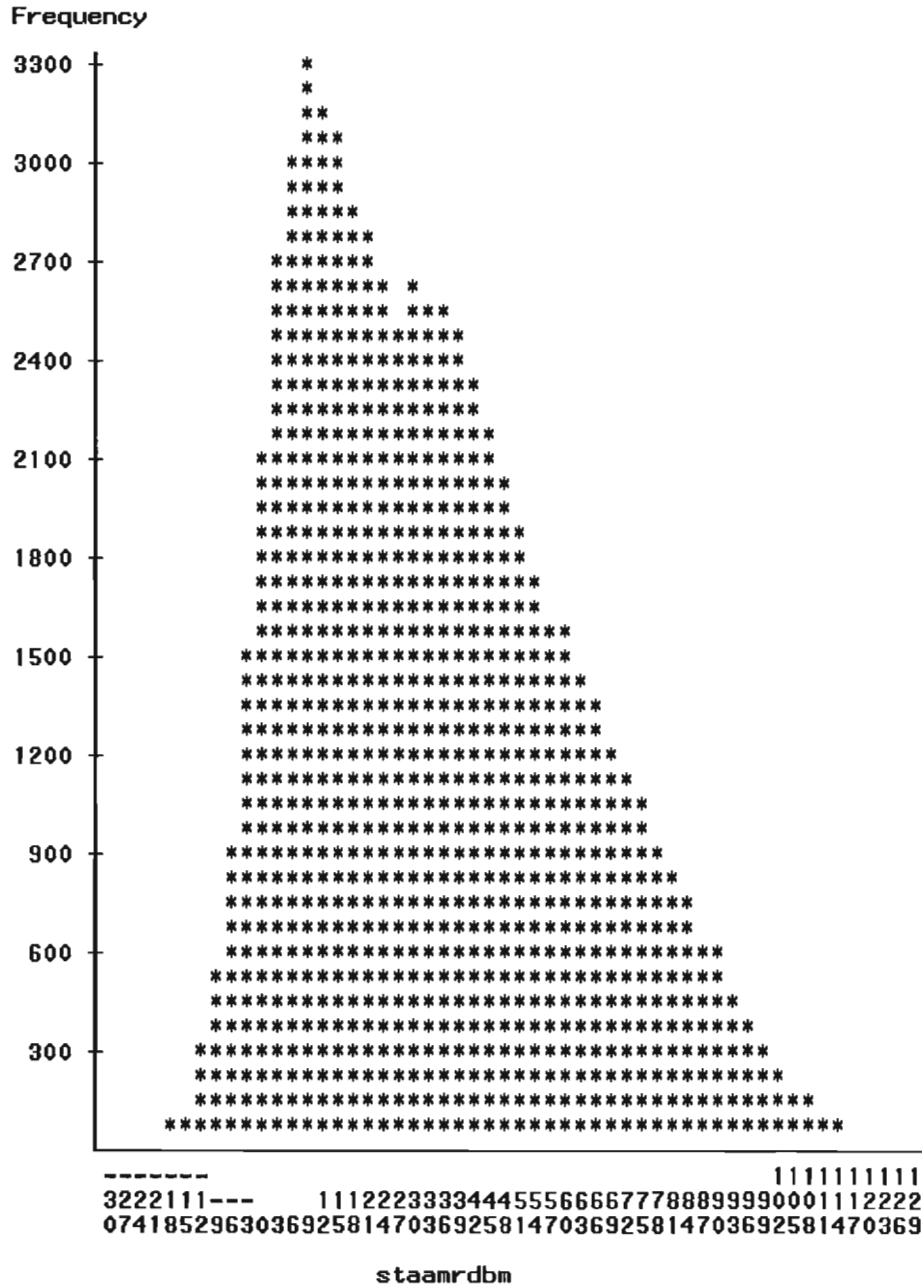
Variable Full Name: Box Up Z Acceleration at Absolute Maximum Resultant Dynamic
Moment (m/s^2)
Abbreviated Name: buaamrdbm



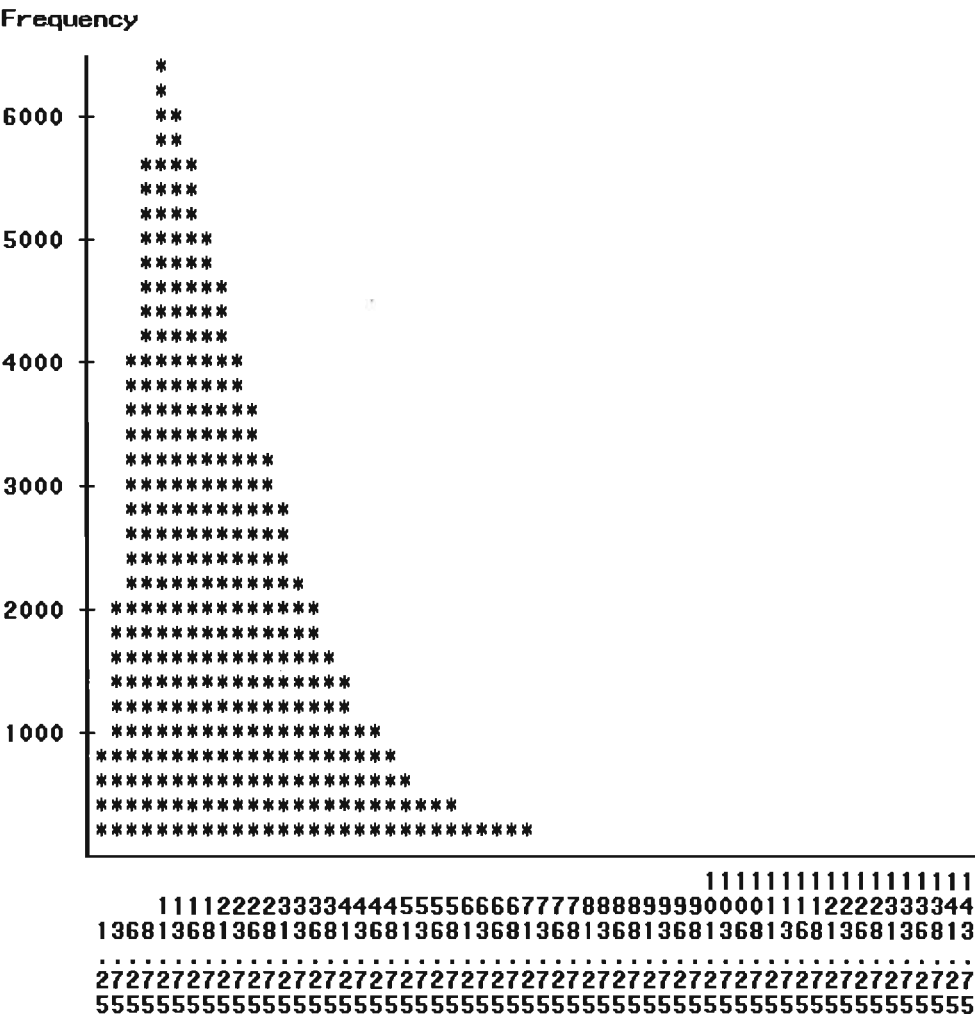
Variable Full Name: Box Down Z Acceleration at Absolute Maximum Resultant Dynamic Moment (m/s²)
Abbreviated Name: bdaamrdbm



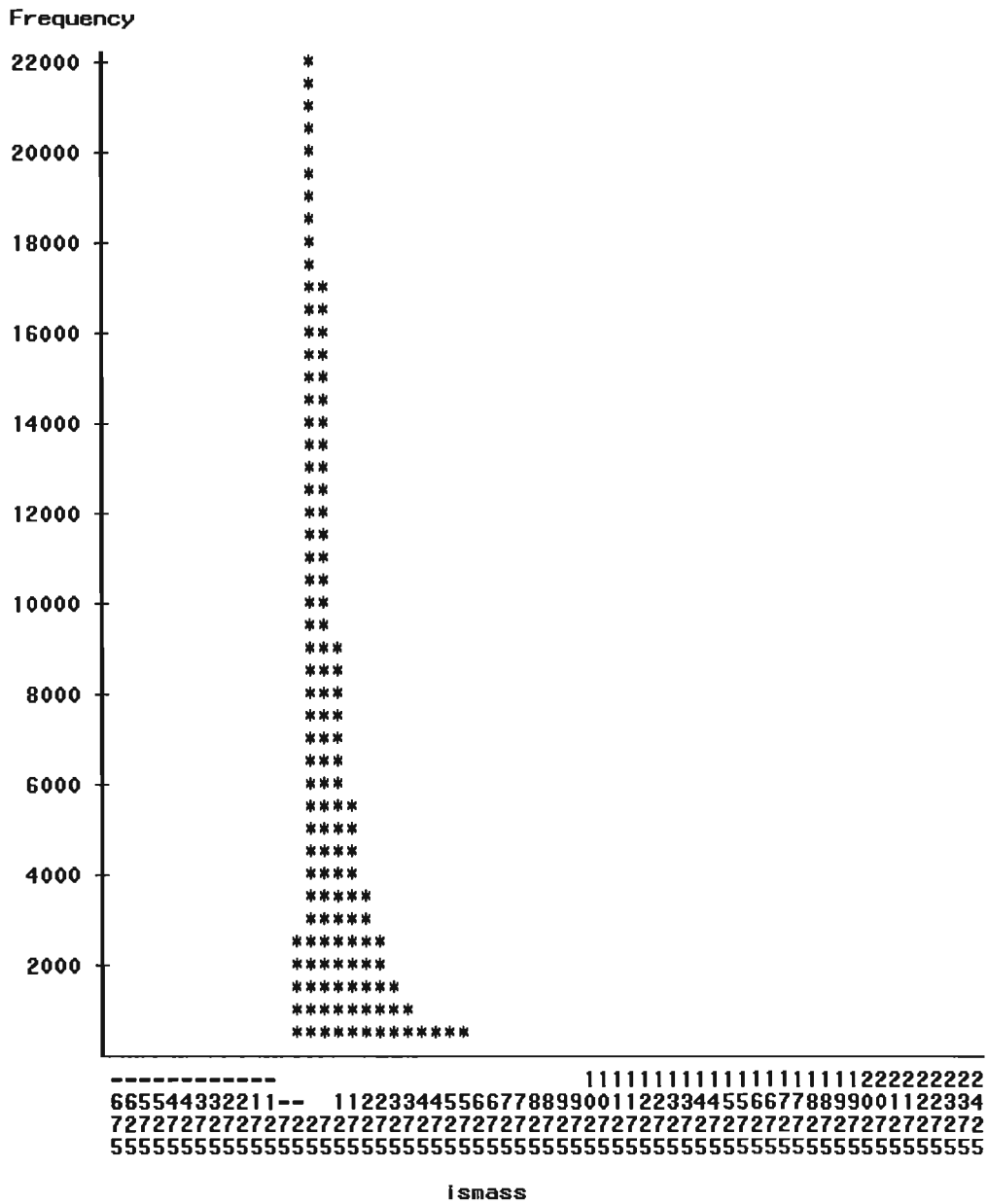
Variable Full Name: Sagittal Trunk Angle at Absolute Maximum Resultant Dynamic
 Moment (Degrees)
 Abbreviated Name: staamrdbm



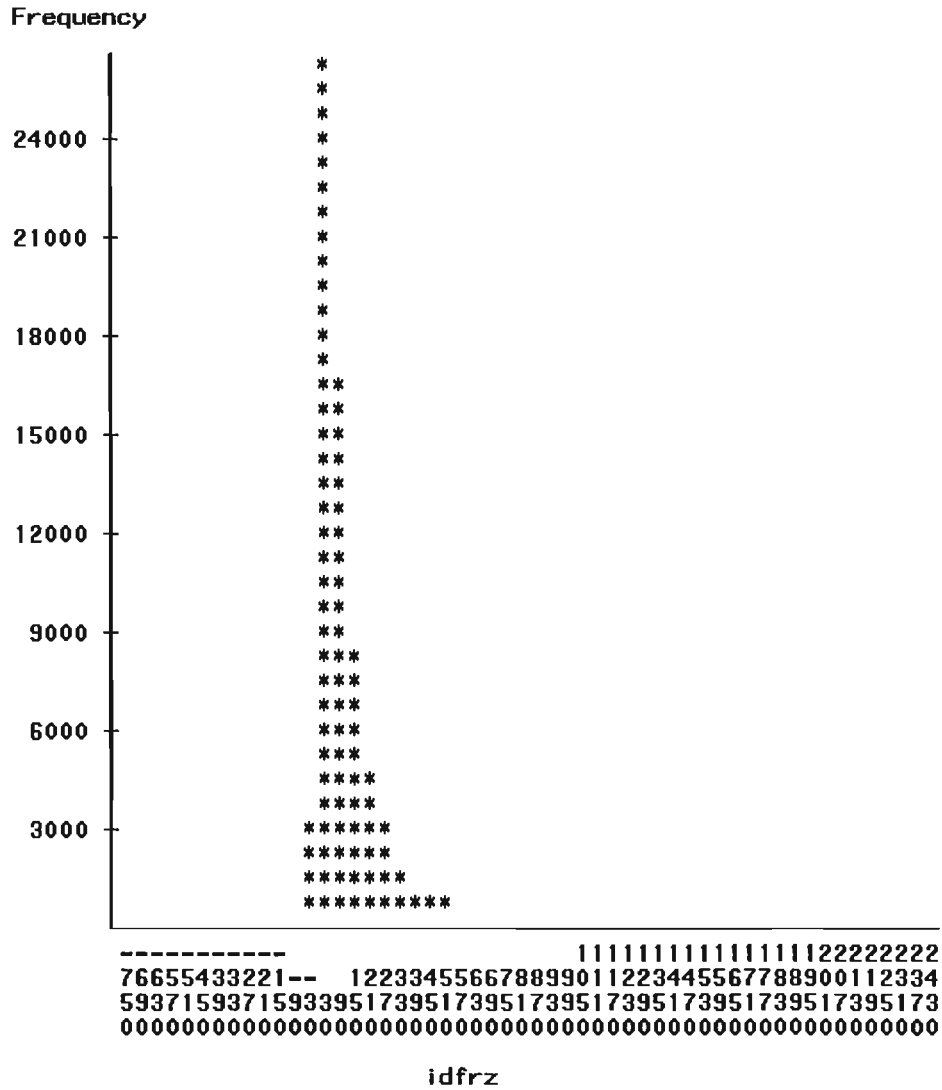
Variable Full Name: Absolute Average Resultant Dynamic Moment (N*m)
Abbreviated Name: aardbm



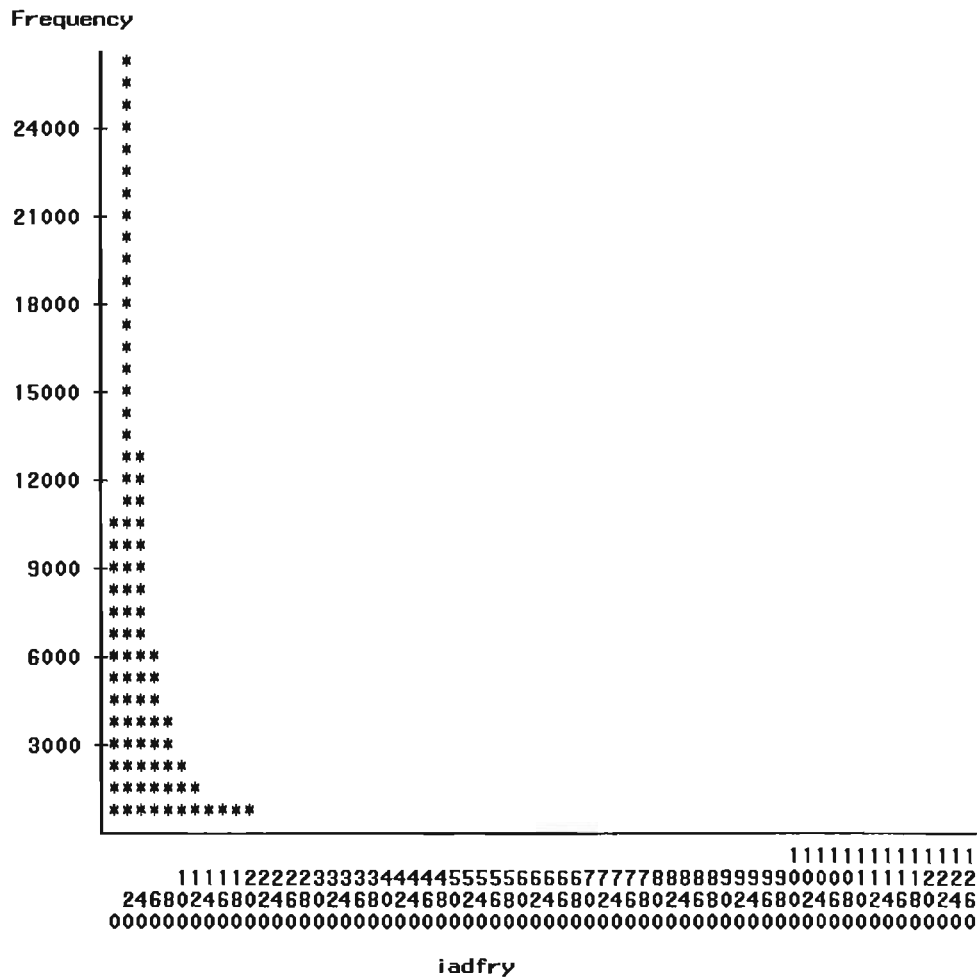
Variable Full Name: Integrated Absolute Box Weight (N)
Abbreviated Name: ismass



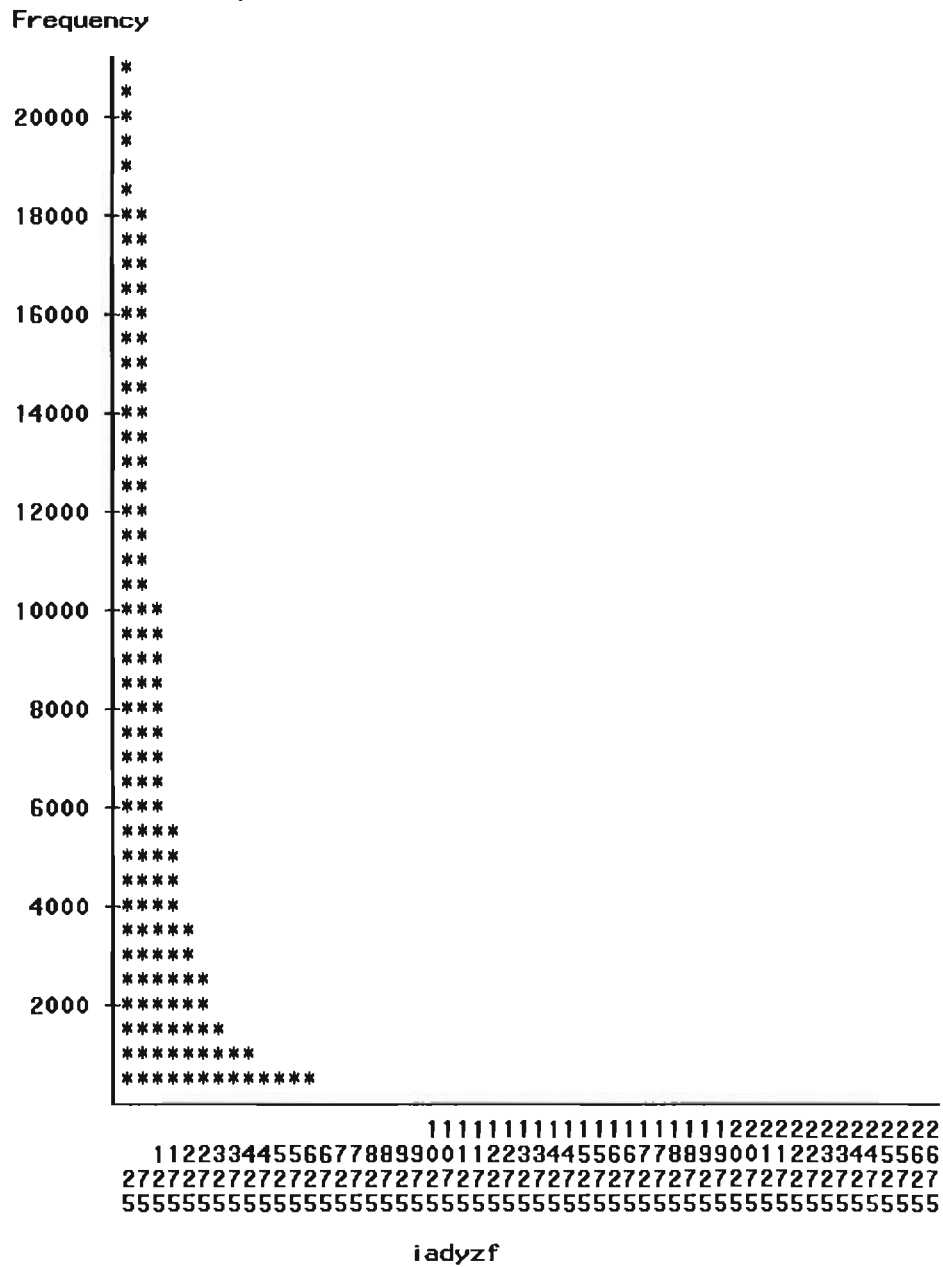
Variable Full Name: Integrated Dynamic Z Force (N)
Abbreviated Name: idfrz



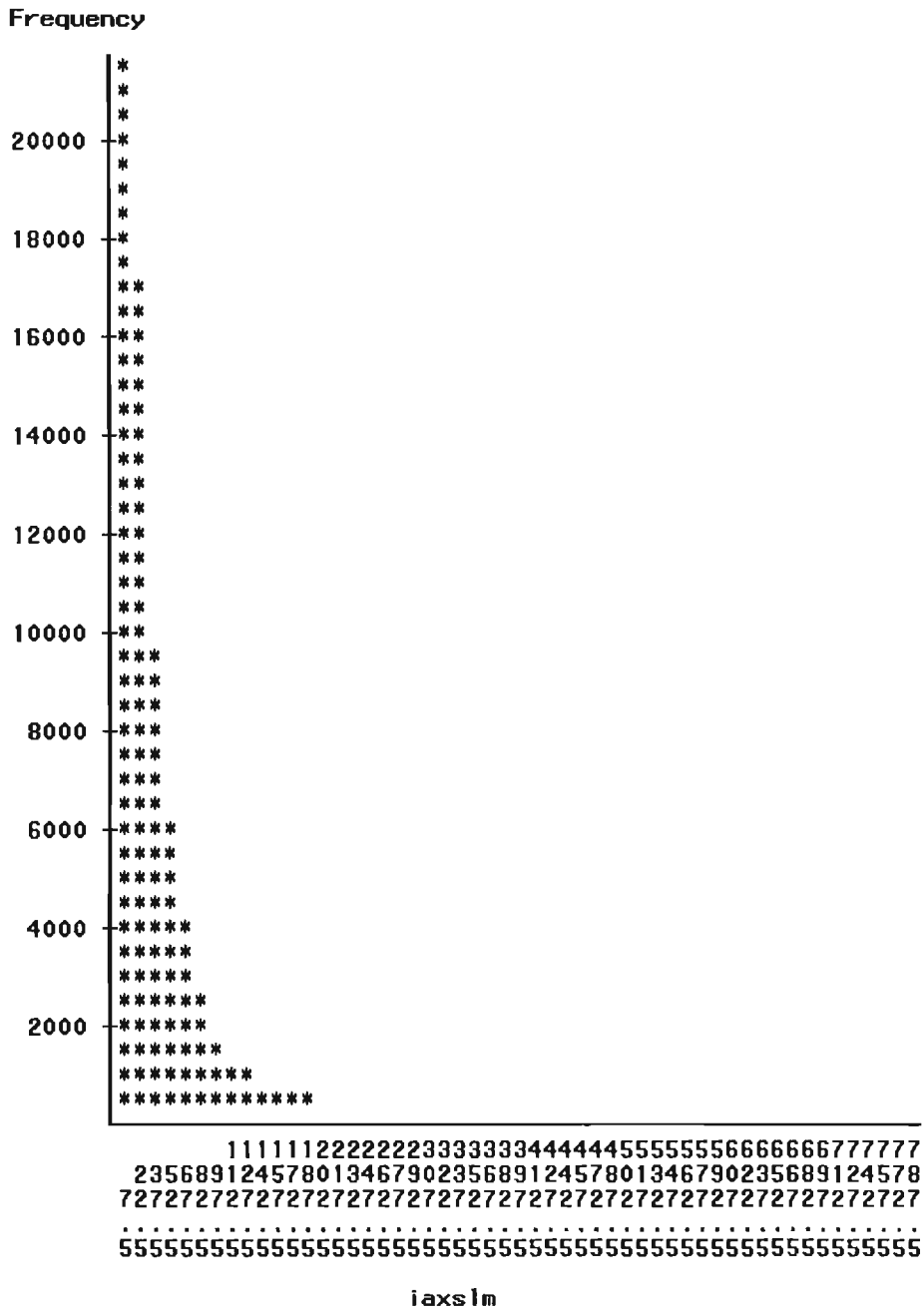
Variable Full Name: Integrated Absolute Dynamic Y Force (N)
Abbreviated Name: iadfry



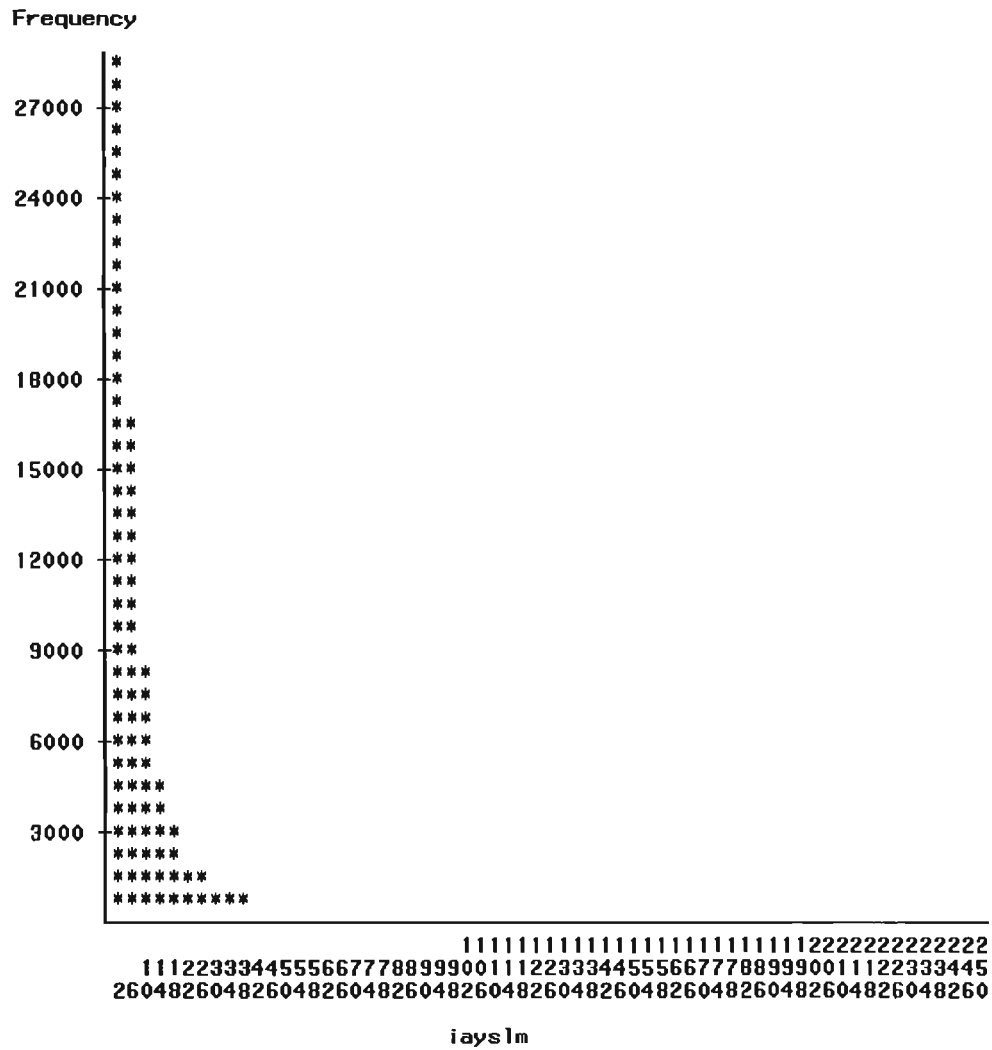
Variable Full Name: Integrated Absolute Dynamic YZ Force (N)
Abbreviated Name: iadyzf



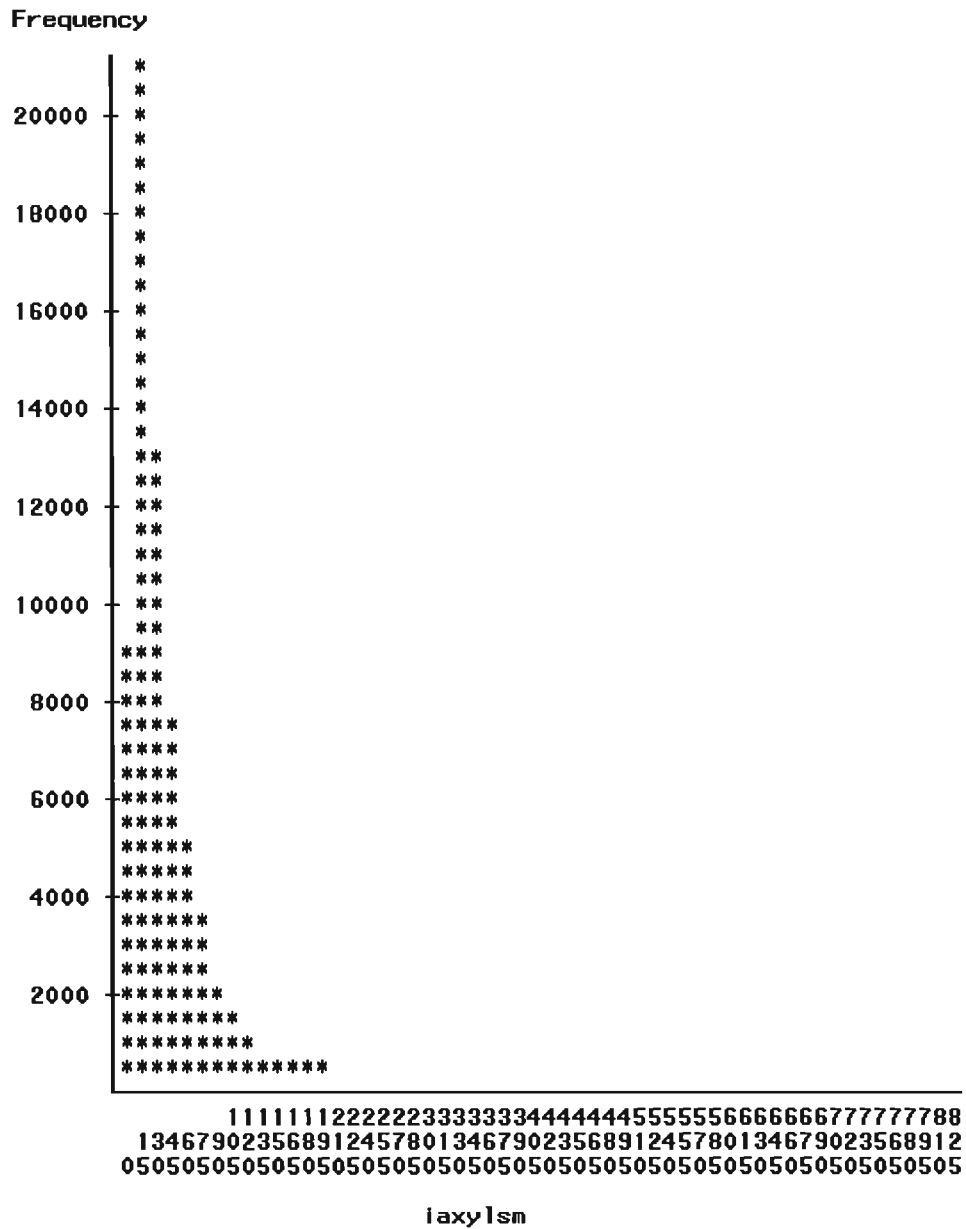
Variable Full Name: Integrated Absolute X-axis Static Lift Moment (N*m)
Abbreviated Name: iaxslm



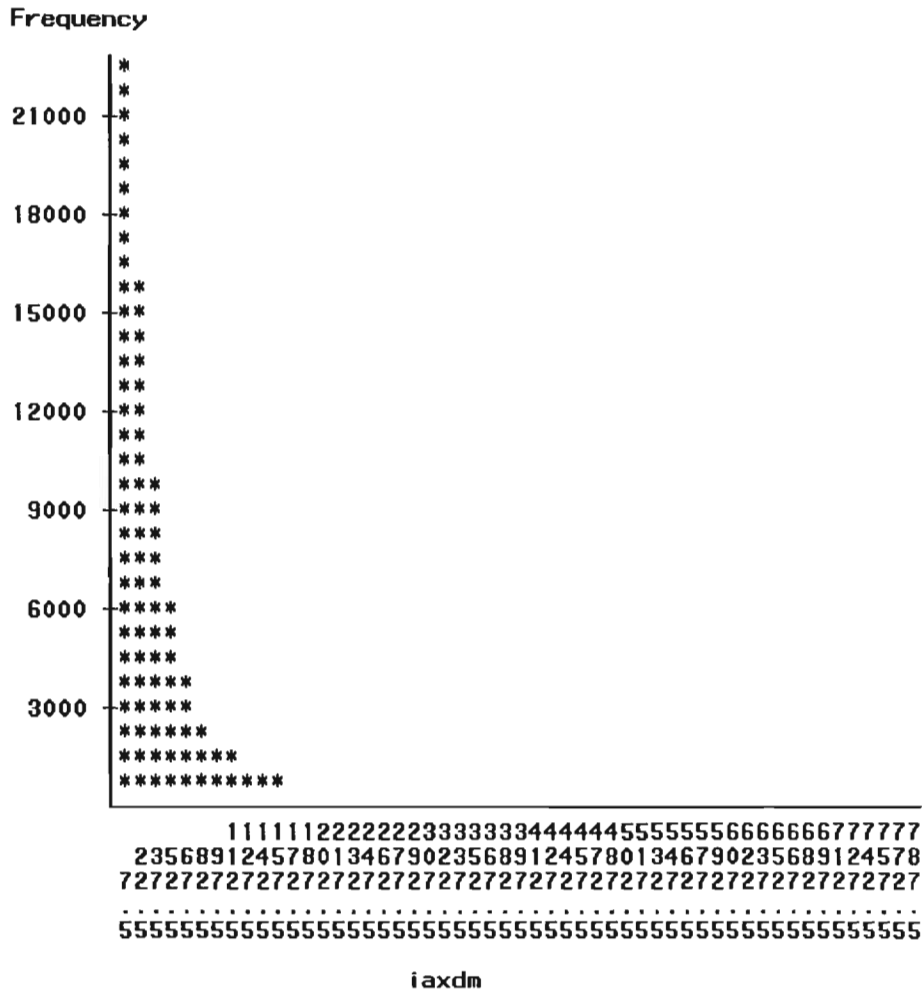
Variable Full Name: Integrated Absolute Y-axis Static Lift Moment (N*m)
Abbreviated Name: iayslm



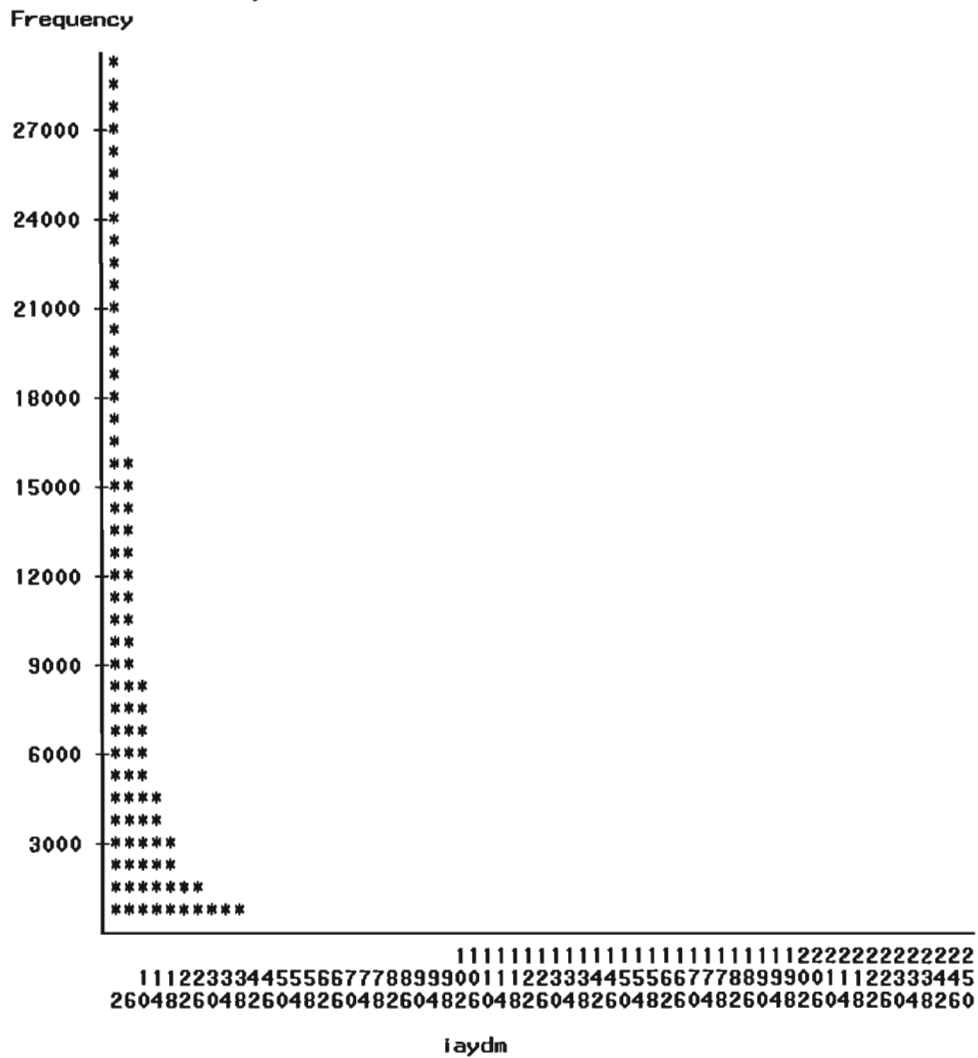
Variable Full Name: Integrated Absolute XY*Lift Static Moment (N*m)
Abbreviated Name: iaxyism



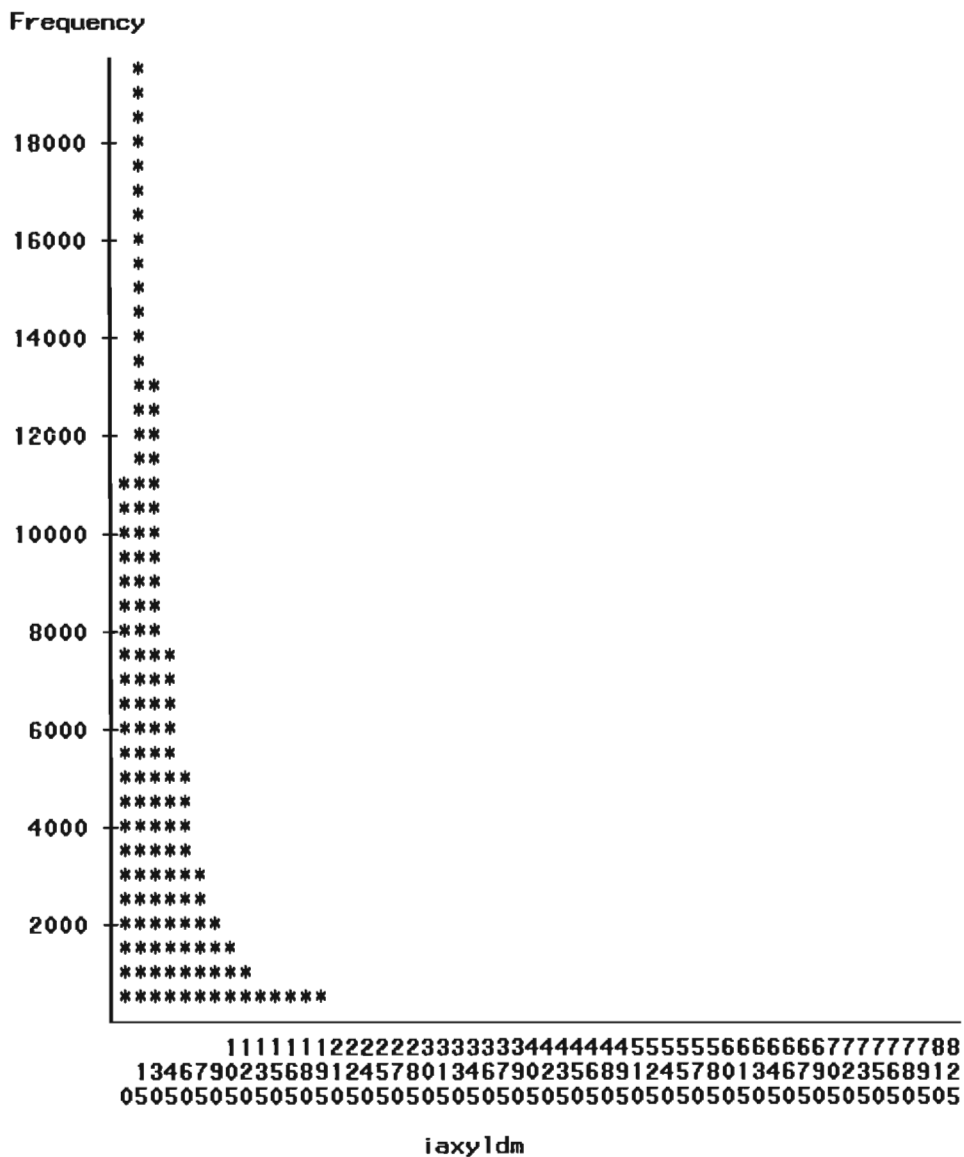
Variable Full Name: Integrated Absolute X-axis Dynamic Moment (N*m)
Abbreviated Name: iaxdm



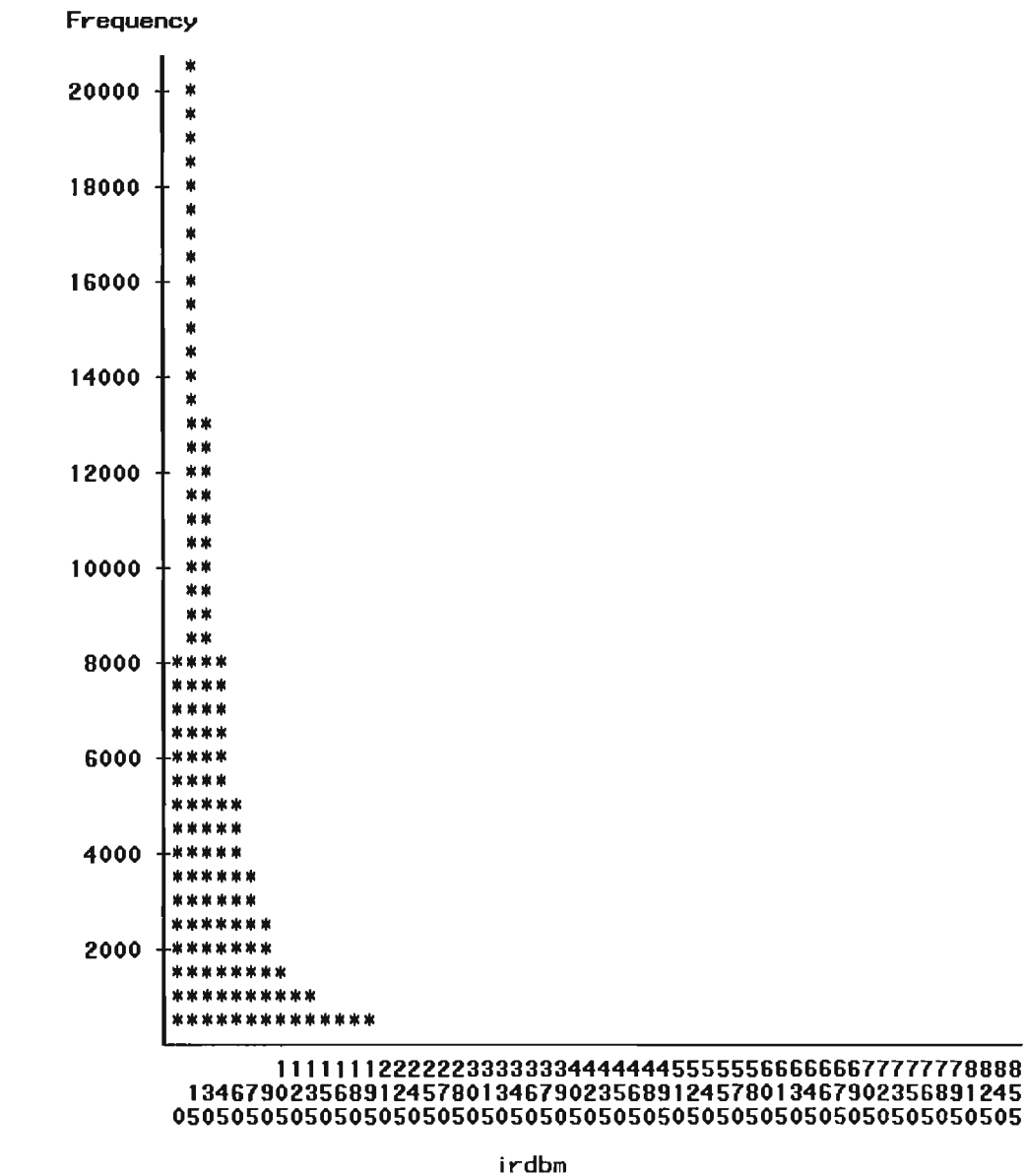
Variable Full Name: Integrated Absolute Y-axis Dynamic Moment (N*m)
Abbreviated Name: iaydm



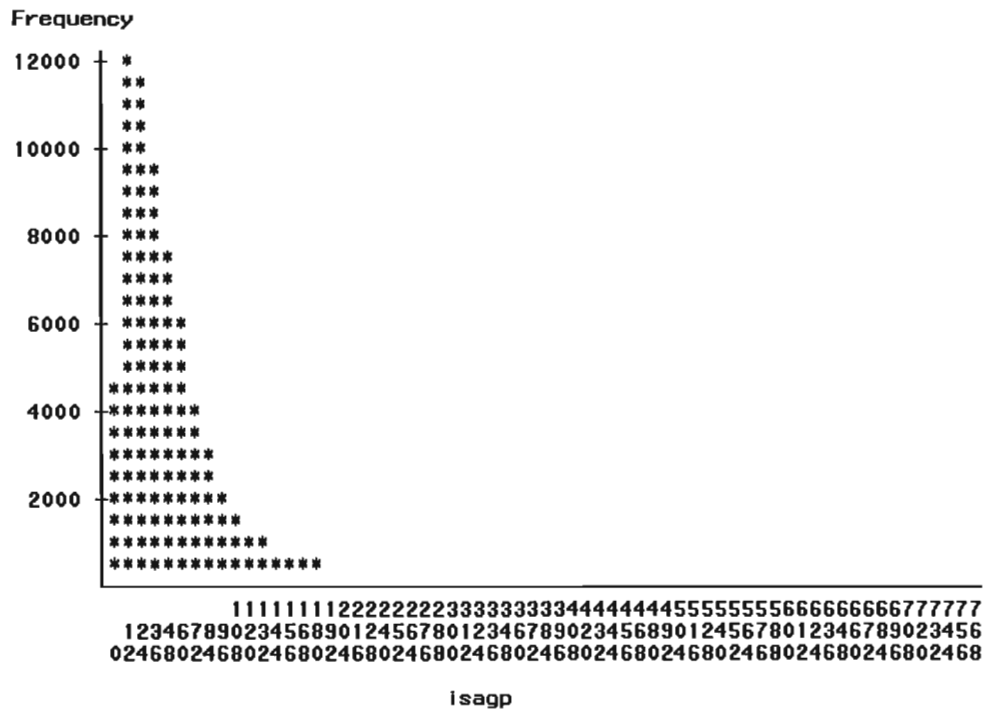
Variable Full Name: Integrated Absolute XY*Lift Dynamic Moment (N*m)
Abbreviated Name: iaxyldm



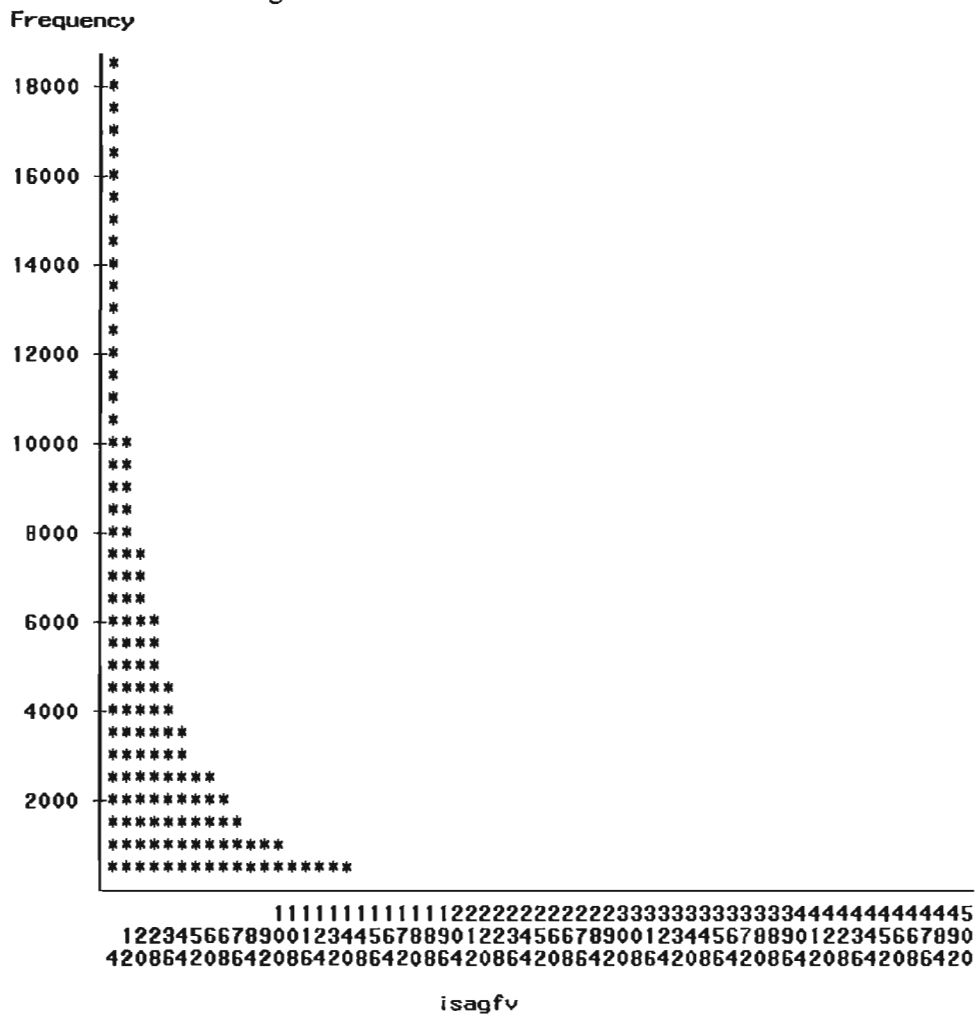
Variable Full Name: Integrated Resultant Dynamic Moment (N*m)
Abbreviated Name: irdbm



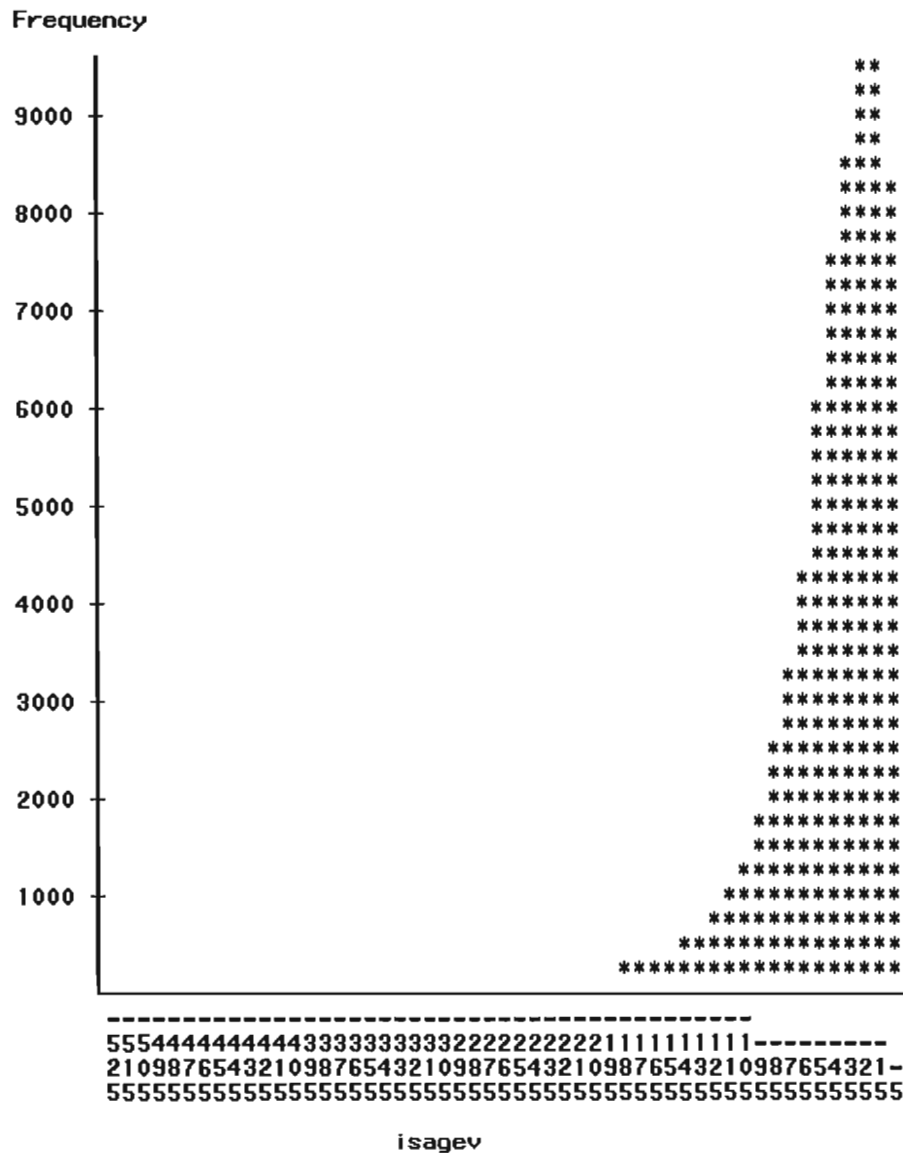
Variable Full Name: Integrated Sagittal Trunk Angle (Degrees)
Abbreviated Name: isagp



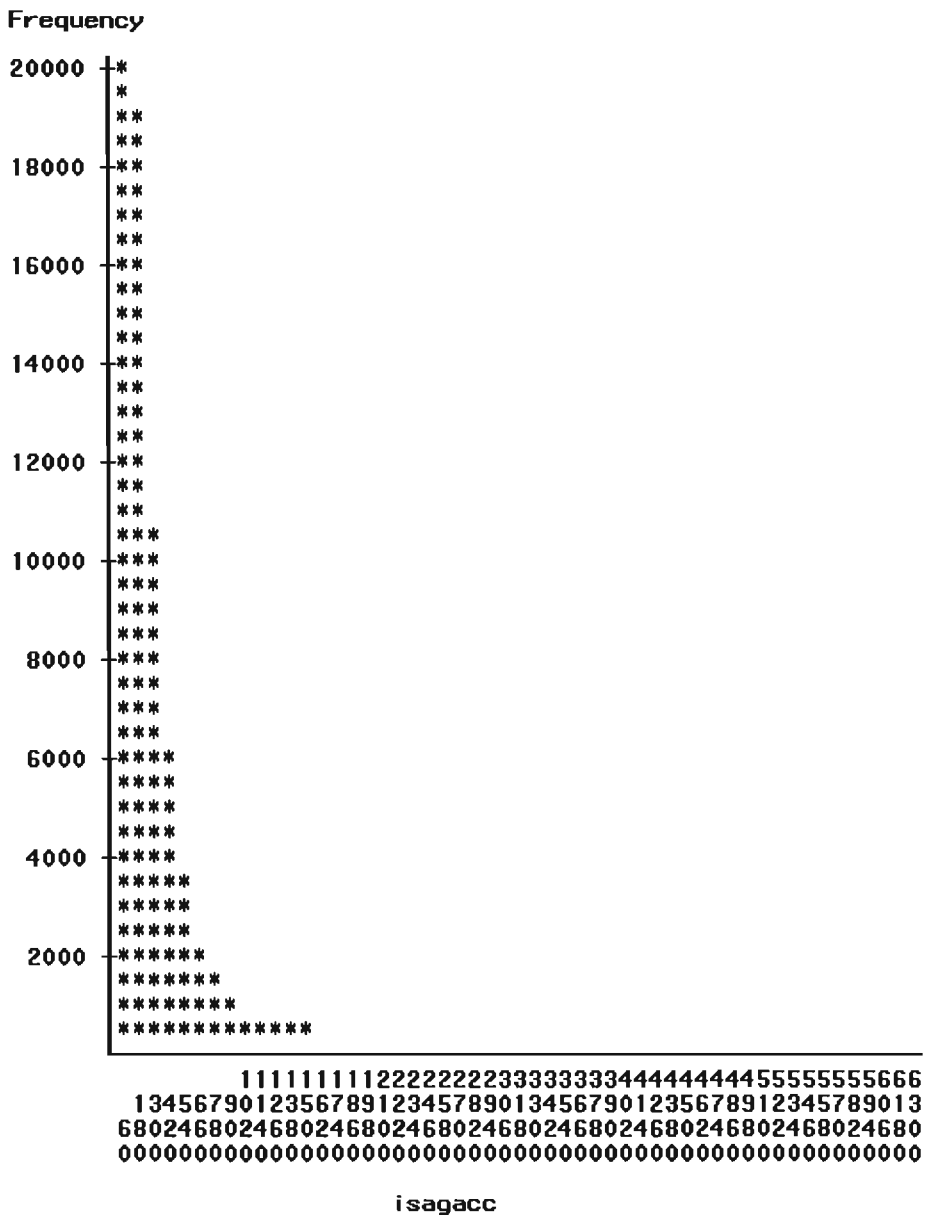
Abbreviated Name: isagfv



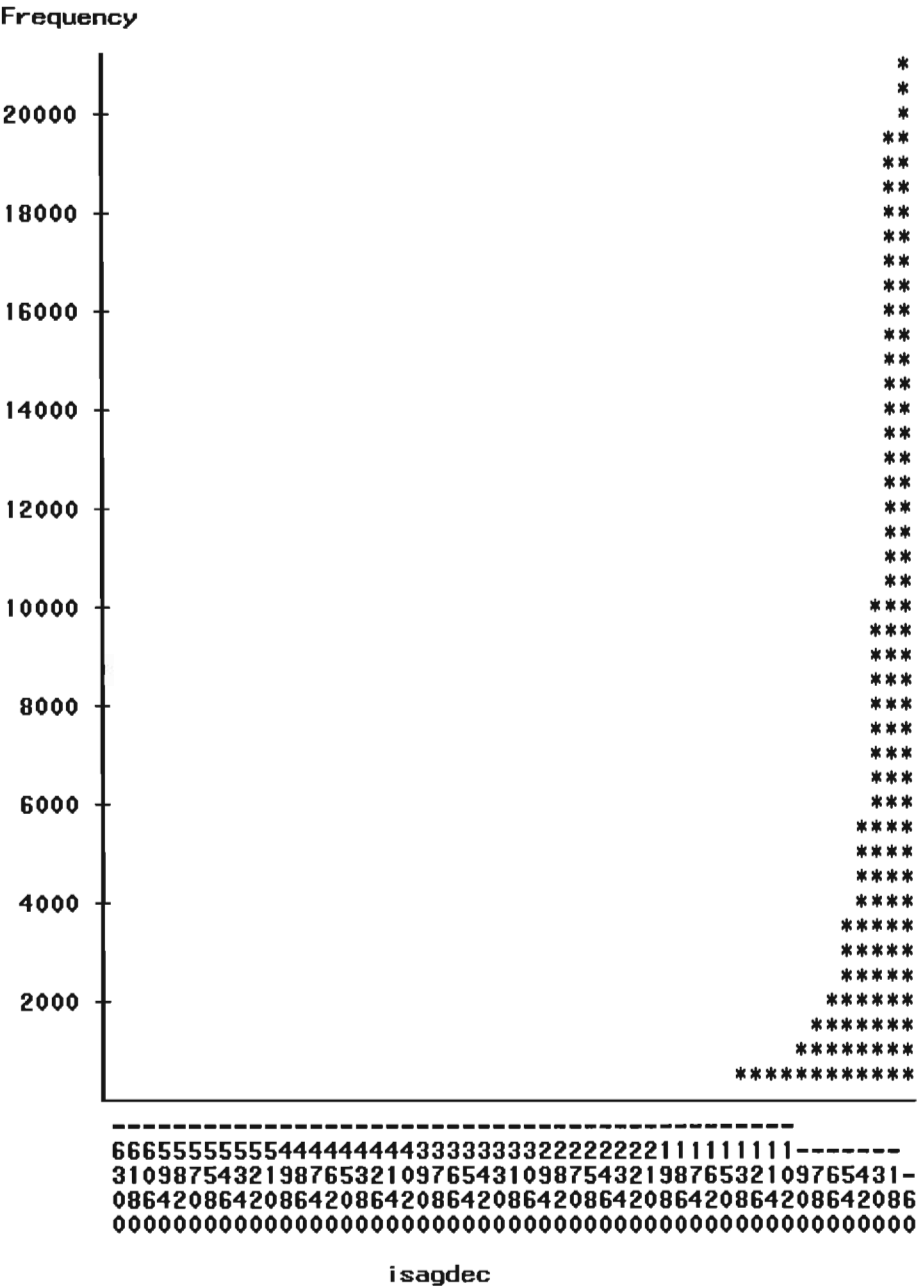
Variable Full Name: Integrated Extension Sagittal Velocity (Degrees/s)
Abbreviated Name: isagev



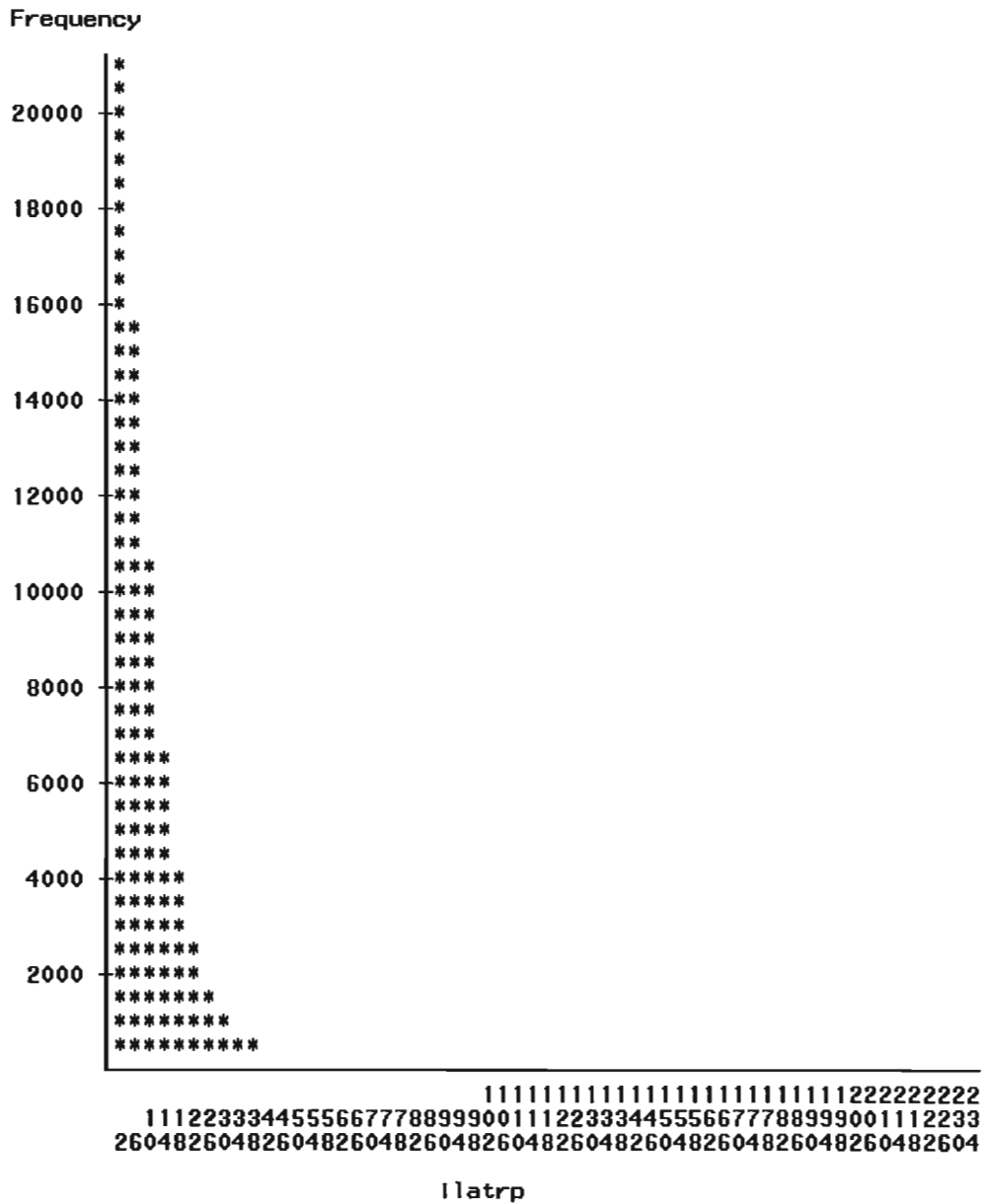
Variable Full Name: Integrated Sagittal Acceleration (Degrees/s^2)
Abbreviated Name: isagacc



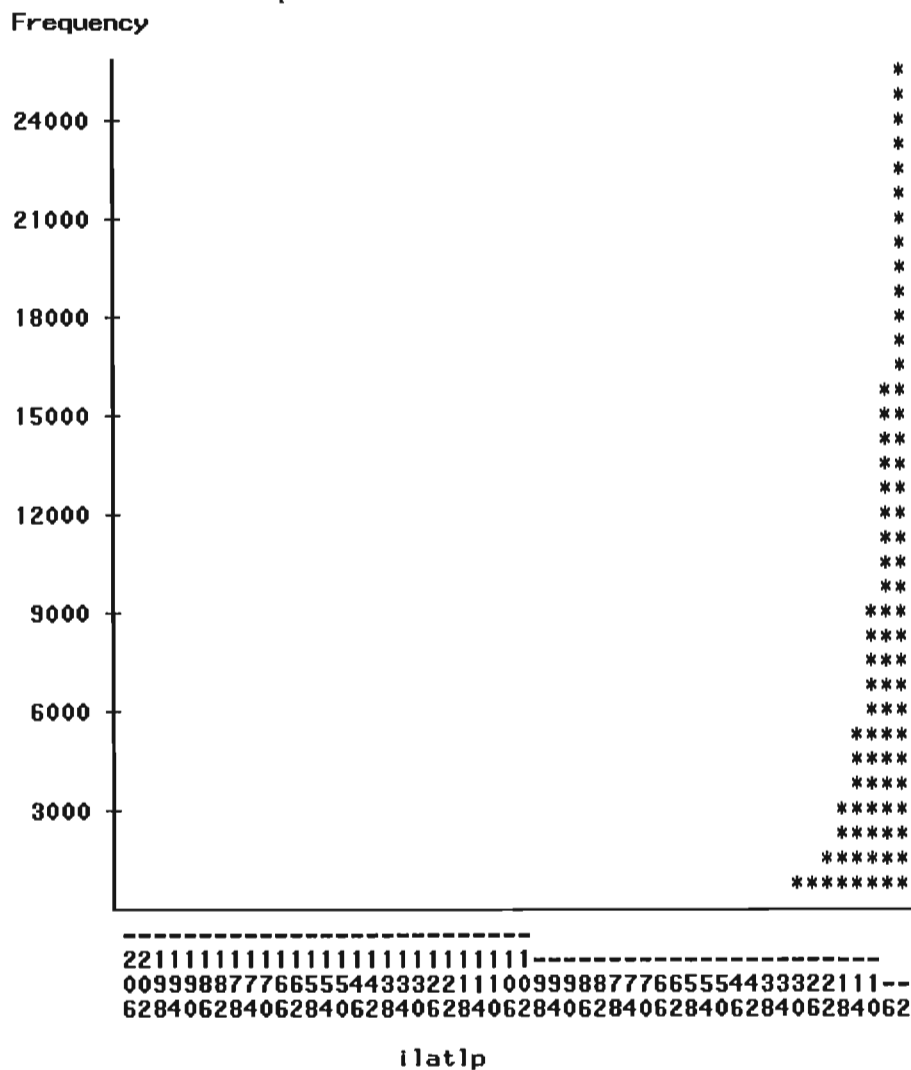
Variable Full Name: Integrated Sagittal Deceleration (Degrees/s^2)
Abbreviated Name: isagdec



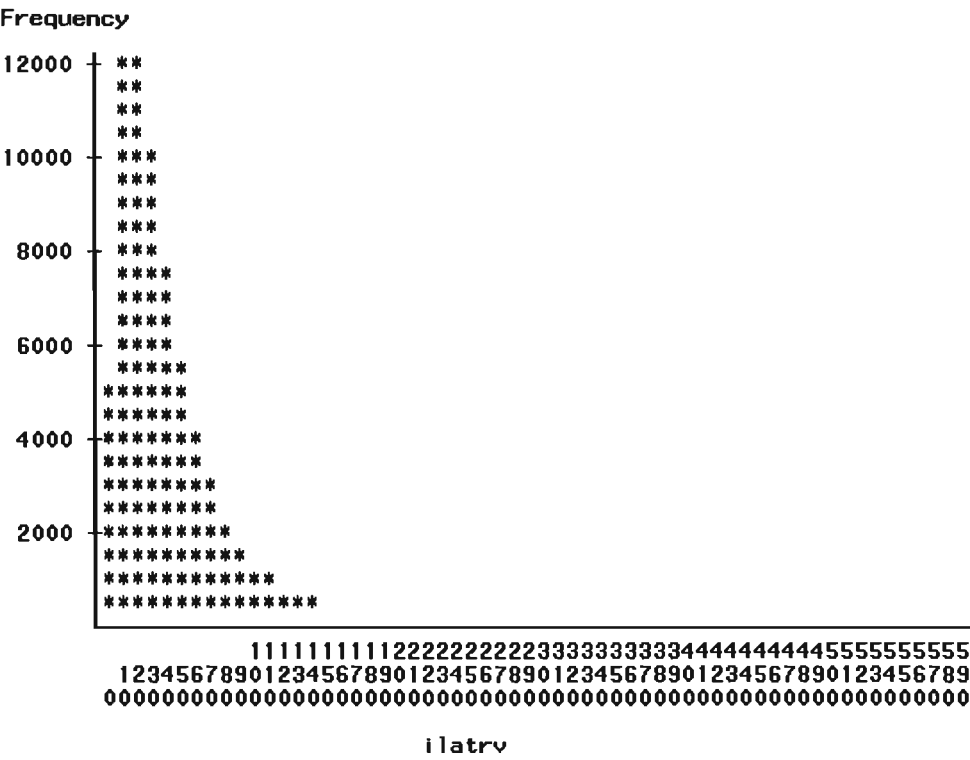
Variable Full Name: Integrated Rightwards Lateral Trunk Angle (Degrees)
Abbreviated Name: ilatrp



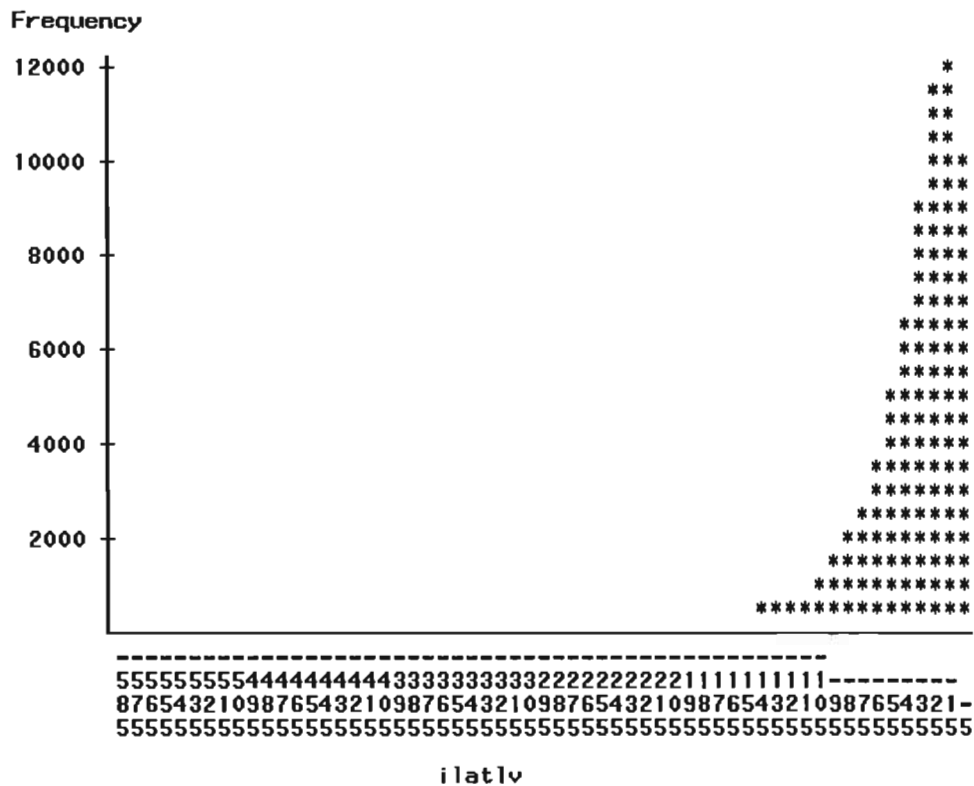
Abbreviated Name: ilatlp



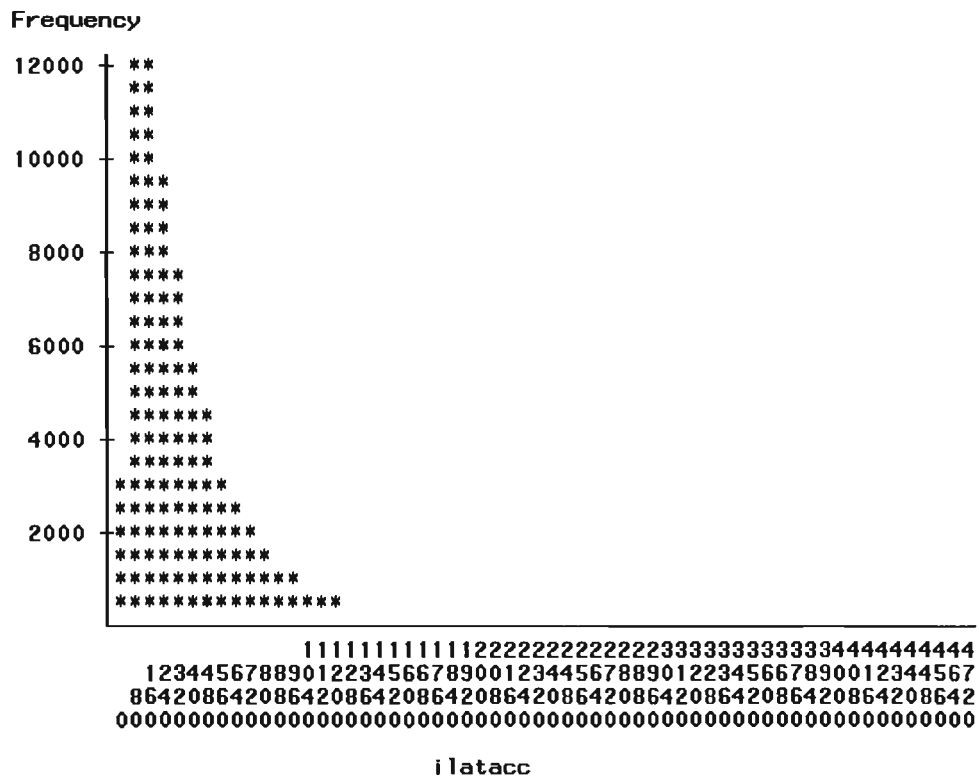
Variable Full Name: Integrated Rightwards Lateral Velocity (Degrees/s)
Abbreviated Name: ilatrv



Variable Full Name: Integrated Leftwards Lateral Velocity (Degrees/s)
Abbreviated Name: ilatlv



Variable Full Name: Integrated Lateral Acceleration (Degrees/s^2)
Abbreviated Name: ilatacc



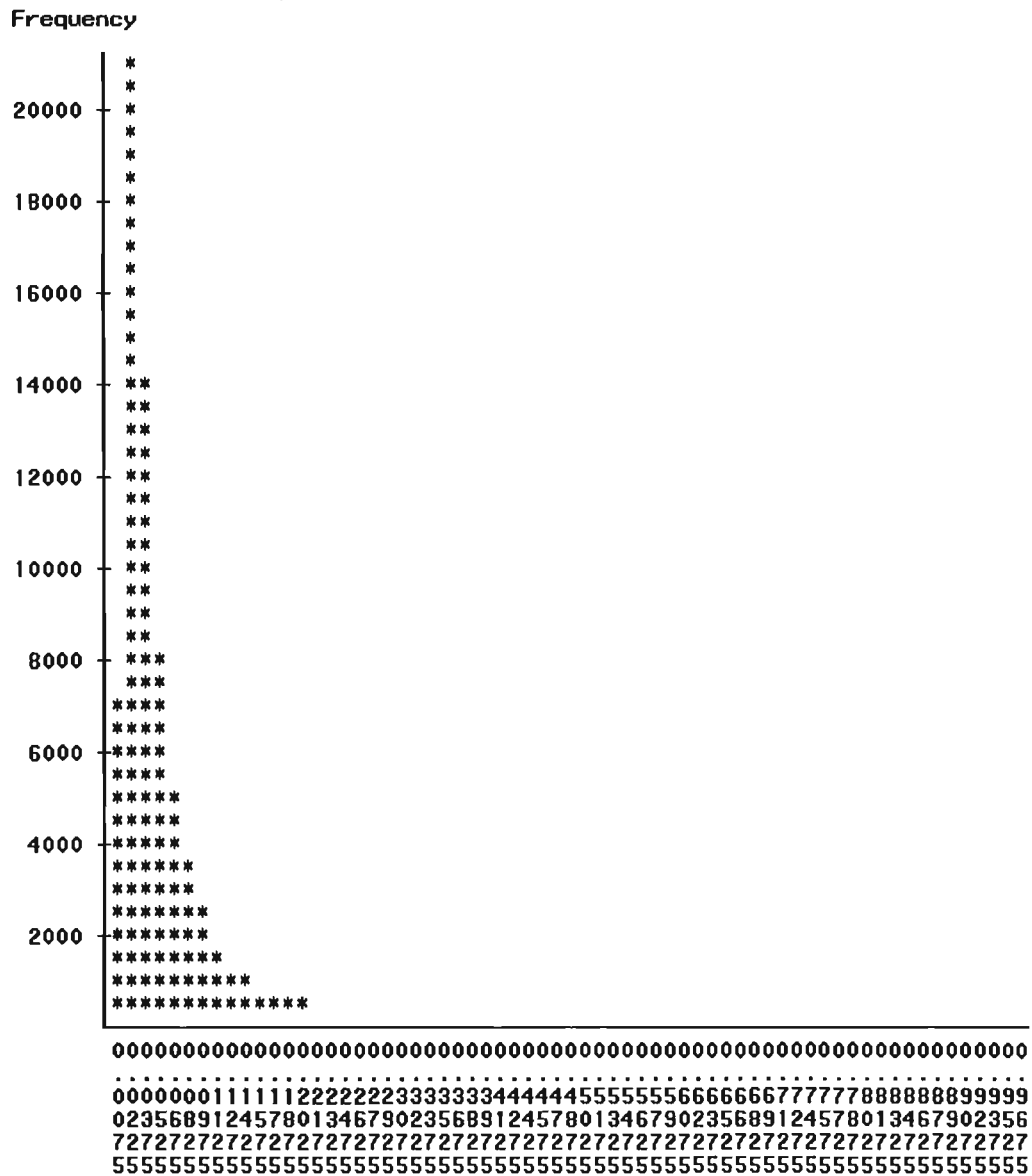
Abbreviated Name: ilatdec



Abbreviated Name: ibxlvel

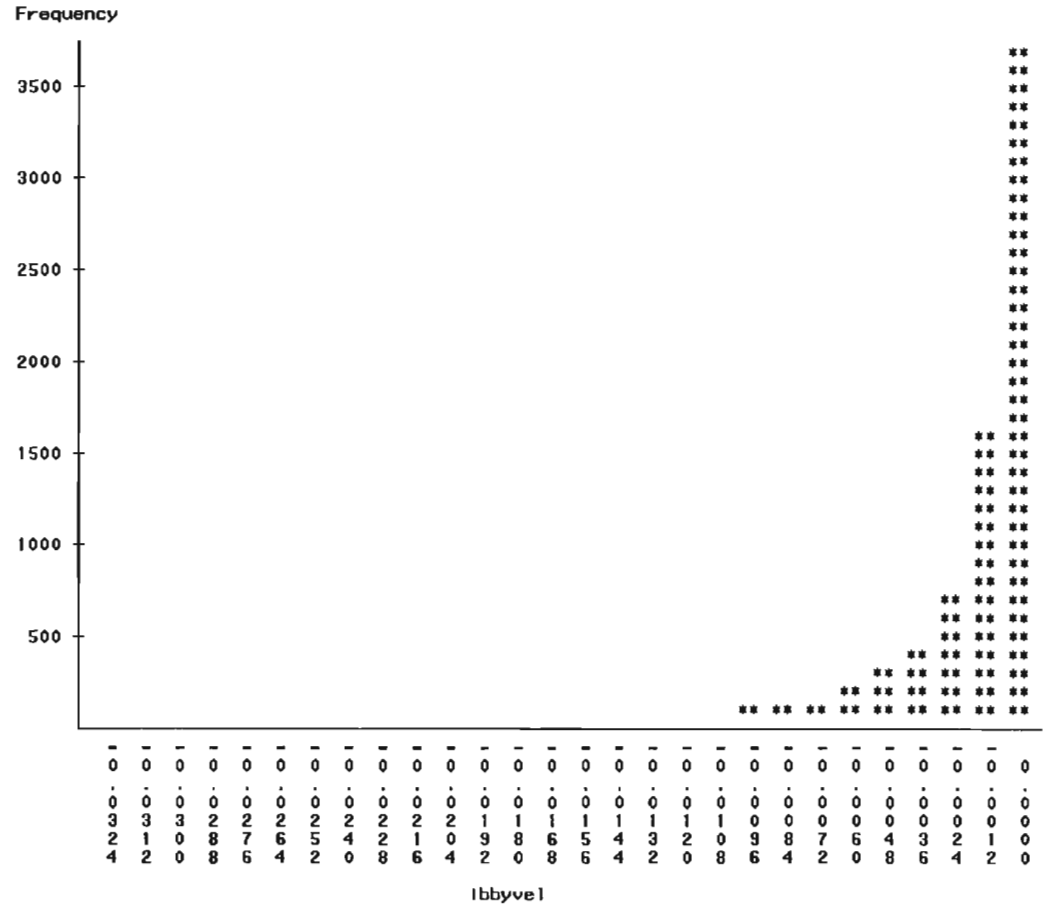


Abbreviated Name: ibfyvel



ibfyvel

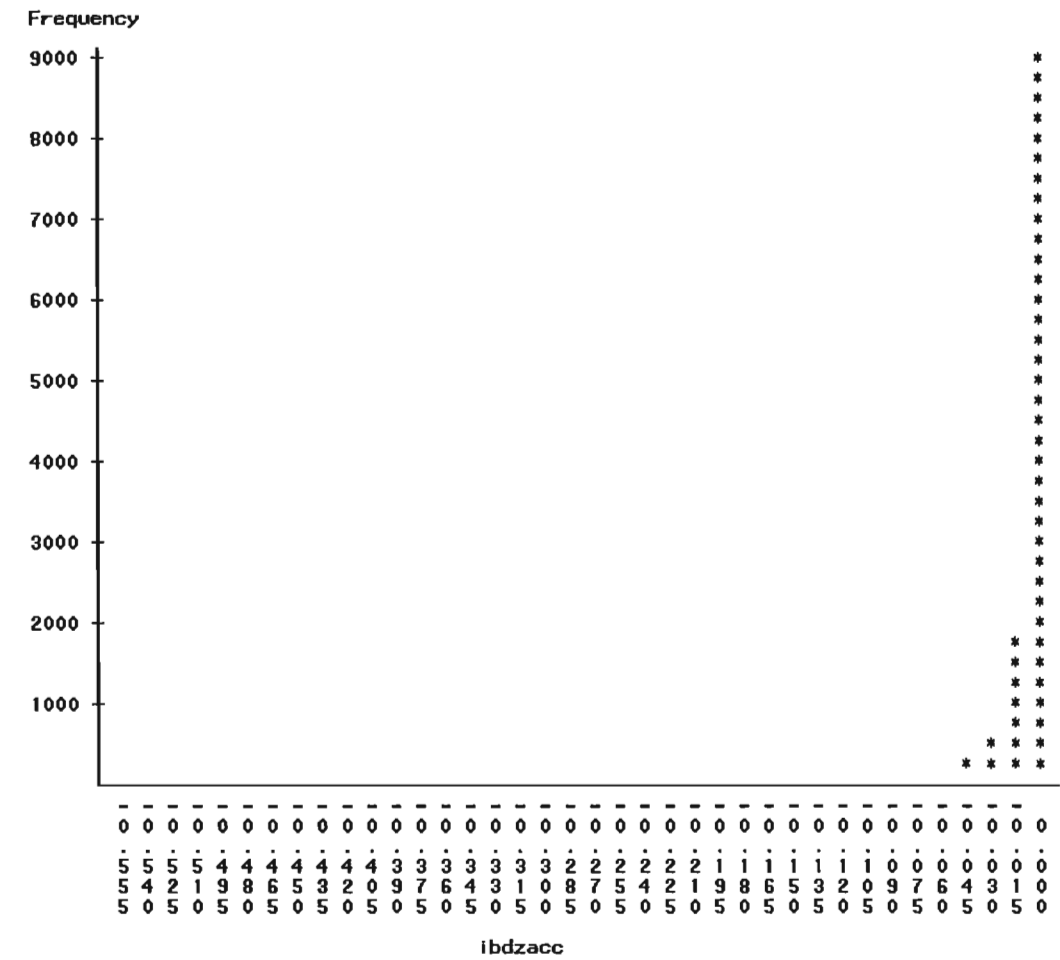
Variable Full Name: Integrated Box Backwards Y Velocity (m/s)
Abbreviated Name: ibbyvel



Abbreviated Name: ibuzacc



Variable Full Name: Integrated Box Down Z Velocity (m/s)
Abbreviated Name: ibdzacc

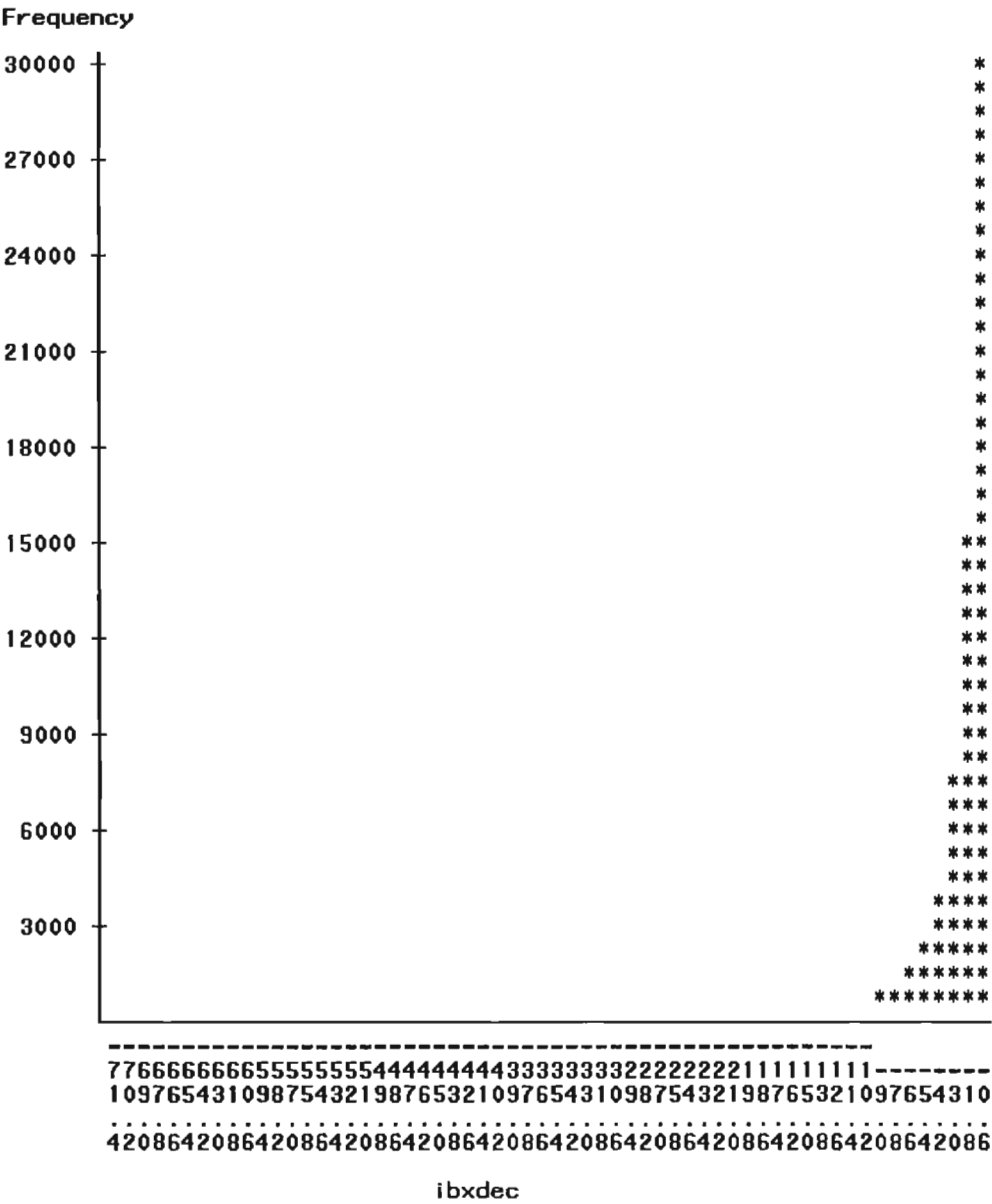


Abbreviated Name: ibrvel

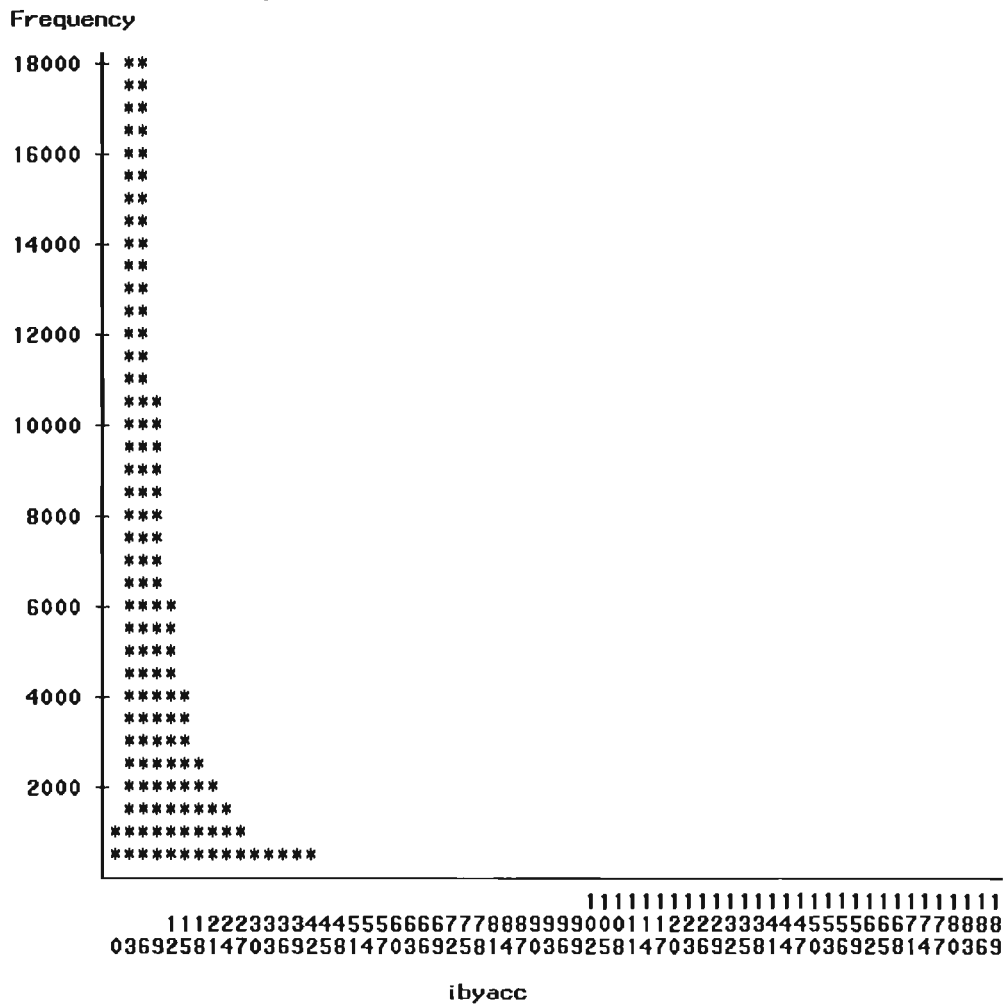
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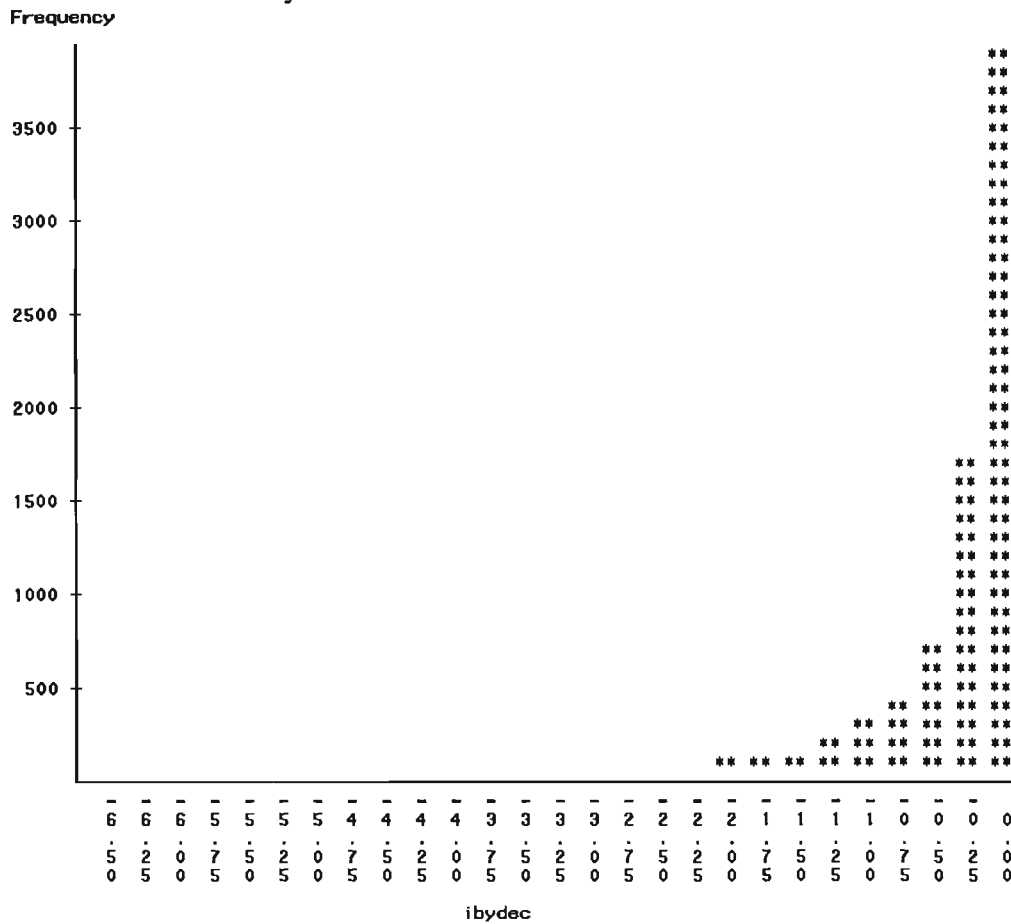
Variable Full Name: Integrated Box X Deceleration (m/s^2)
Abbreviated Name: ibxdec



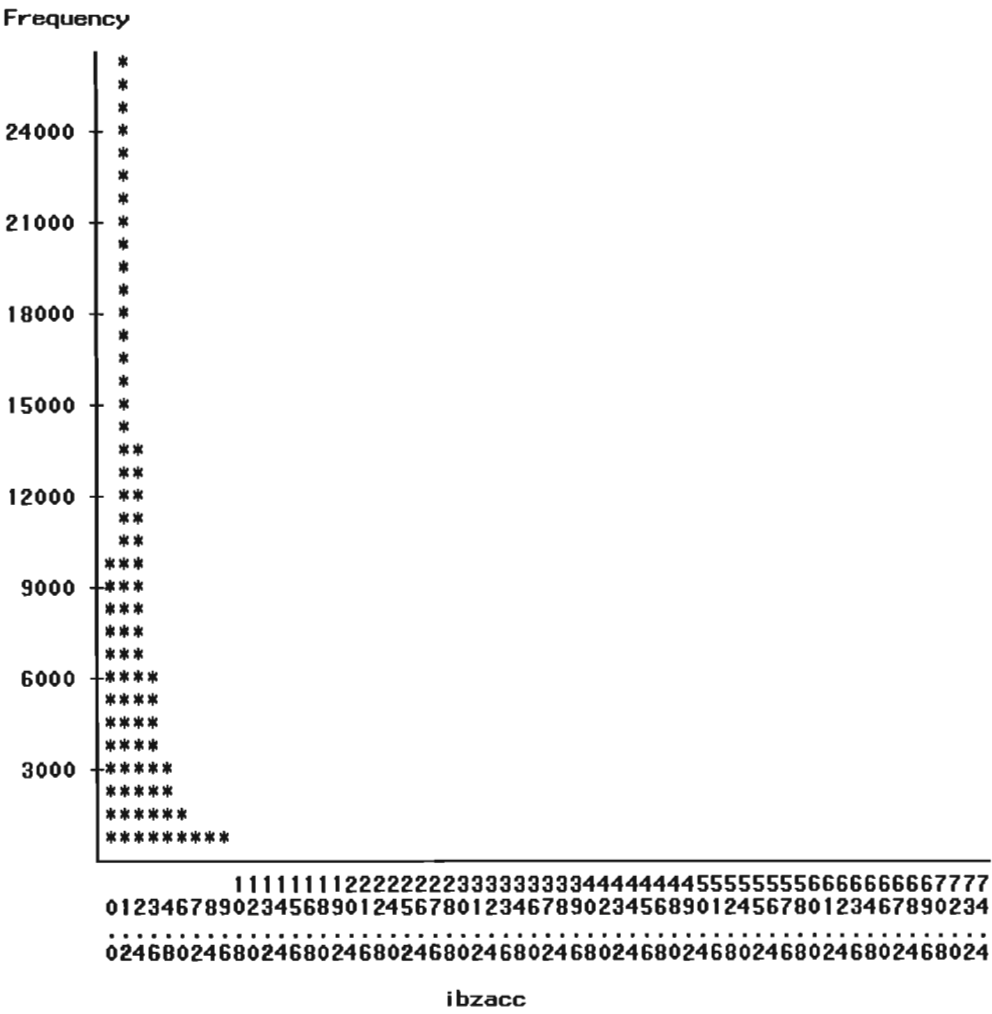
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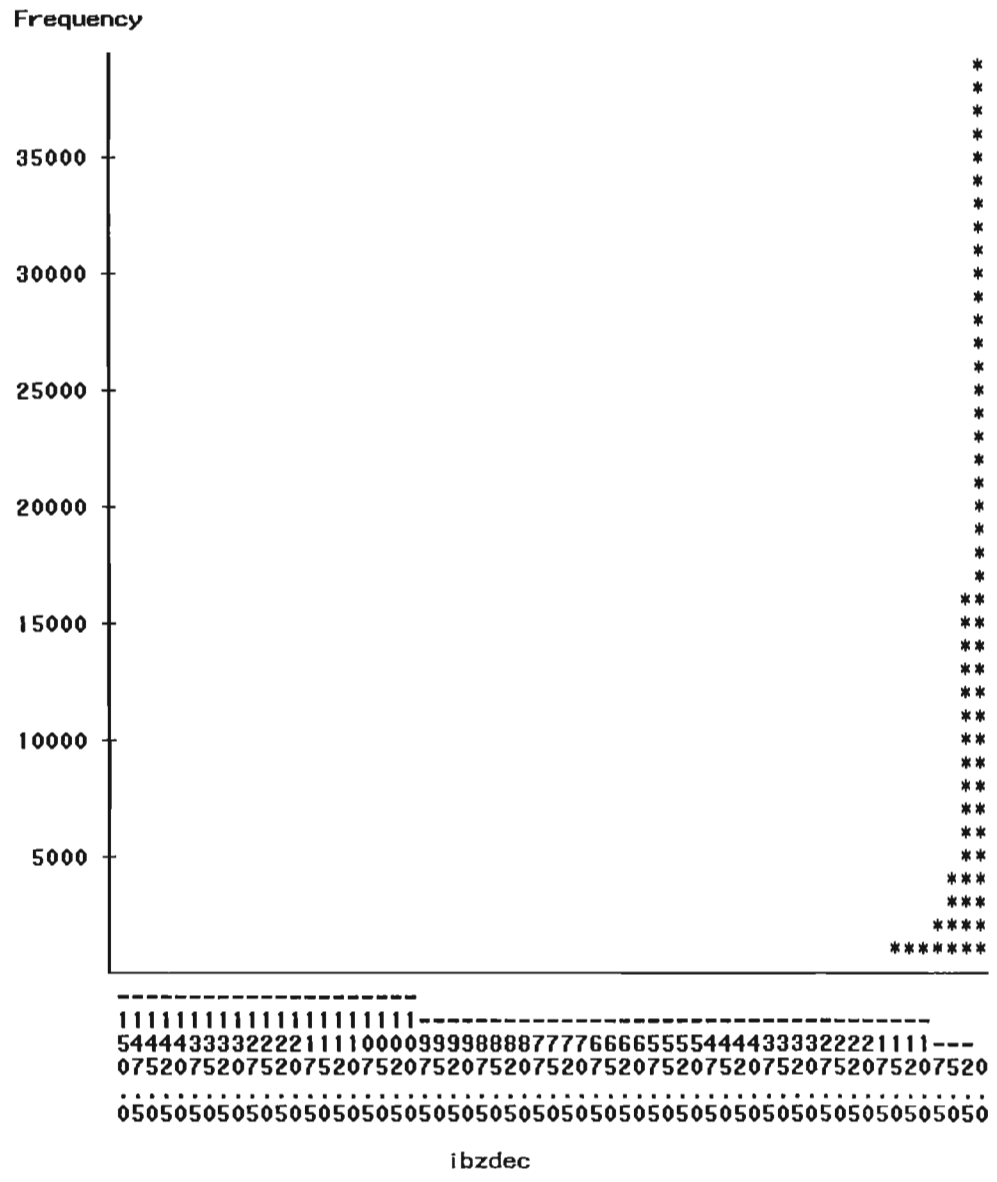
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Variable Full Name: Integrated Box Z Acceleration (m/s^2)
Abbreviated Name: ibzacc



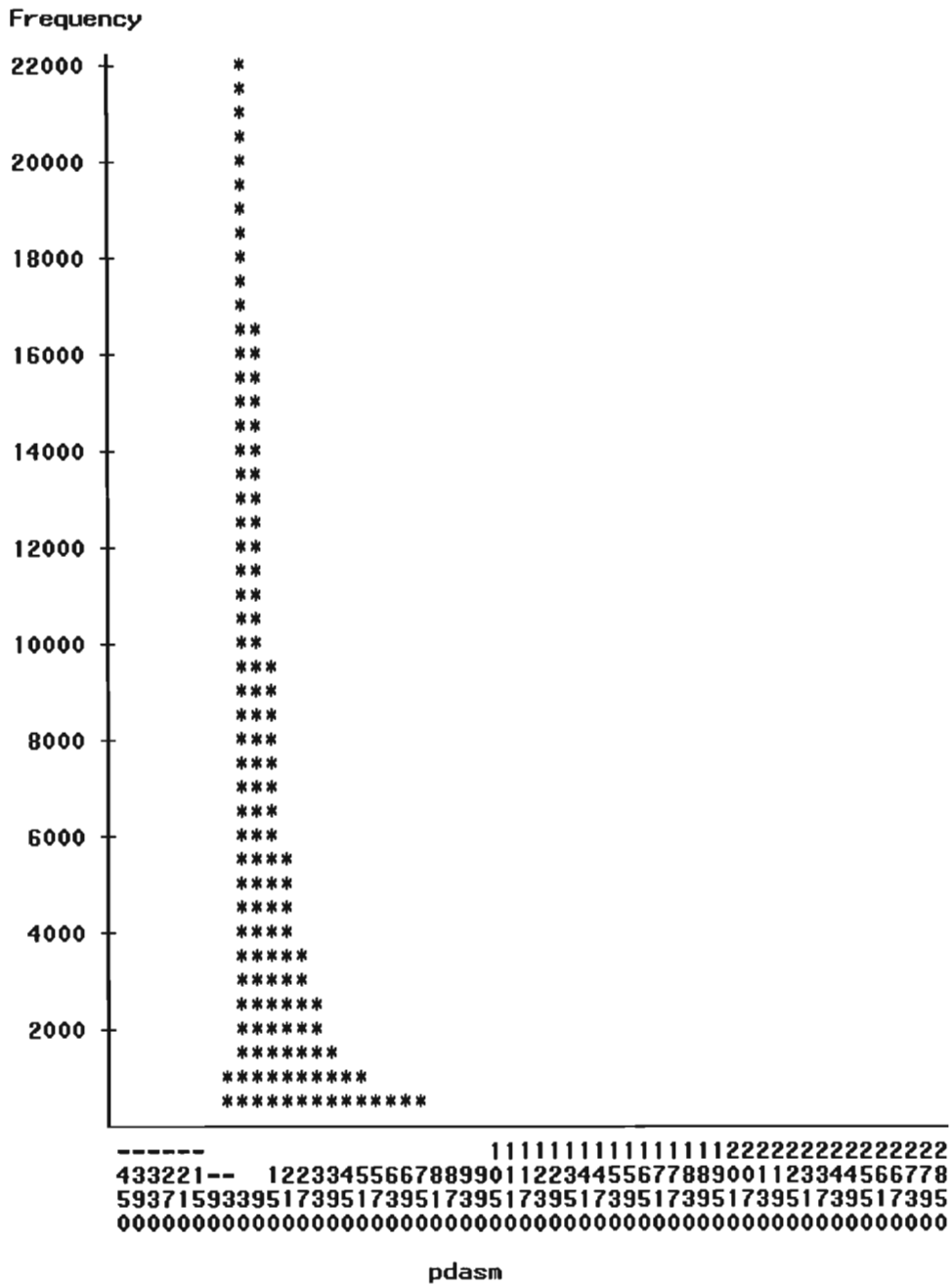
Variable Full Name: Integrated Box Z Deceleration (m/s^2)
Abbreviated Name: ibzdec



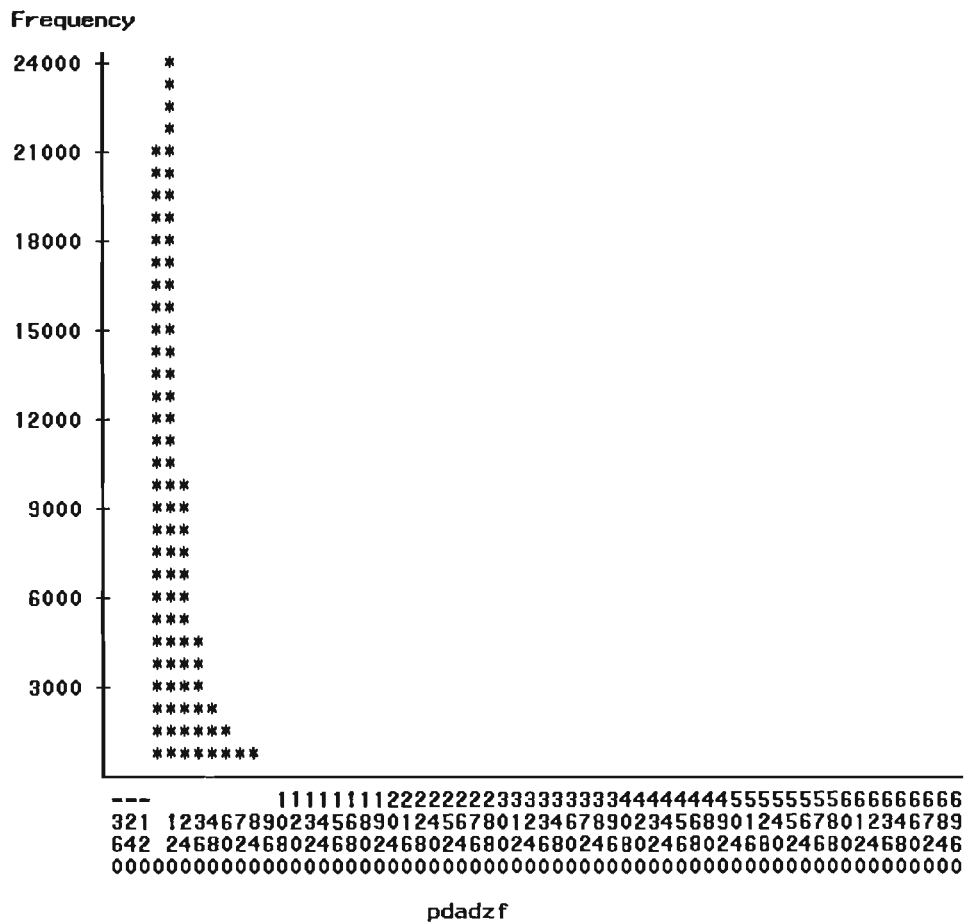
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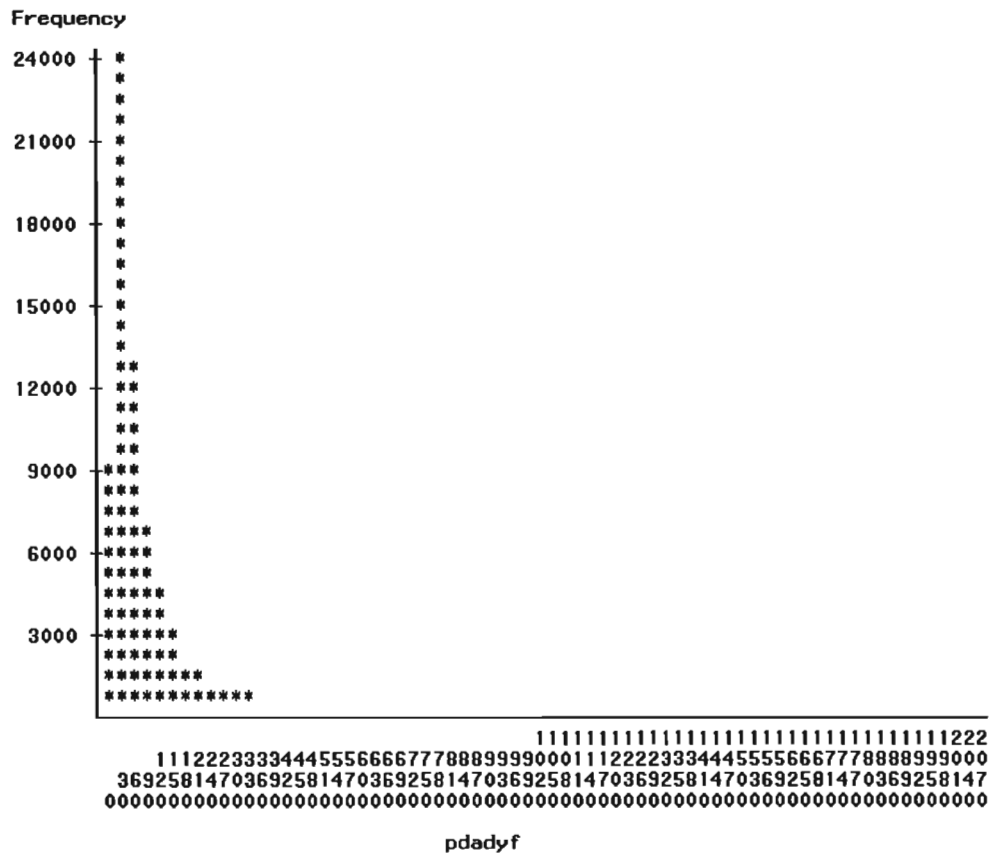
Variable Full Name: Peak*Duration Absolute Box Weight (N)
Abbreviated Name: pdasm



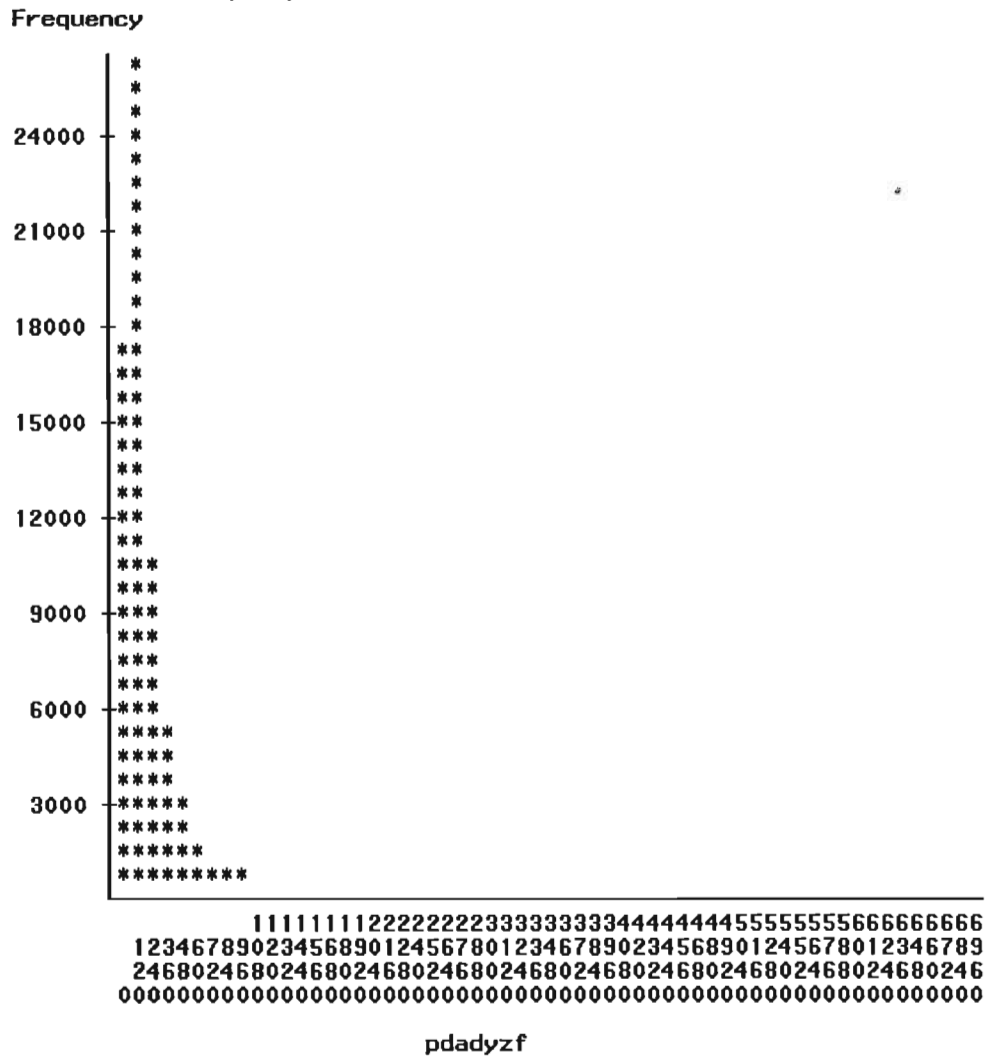
Variable Full Name: Peak*Duration Absolute Dynamic Z Force (N)
Abbreviated Name: pdadzf



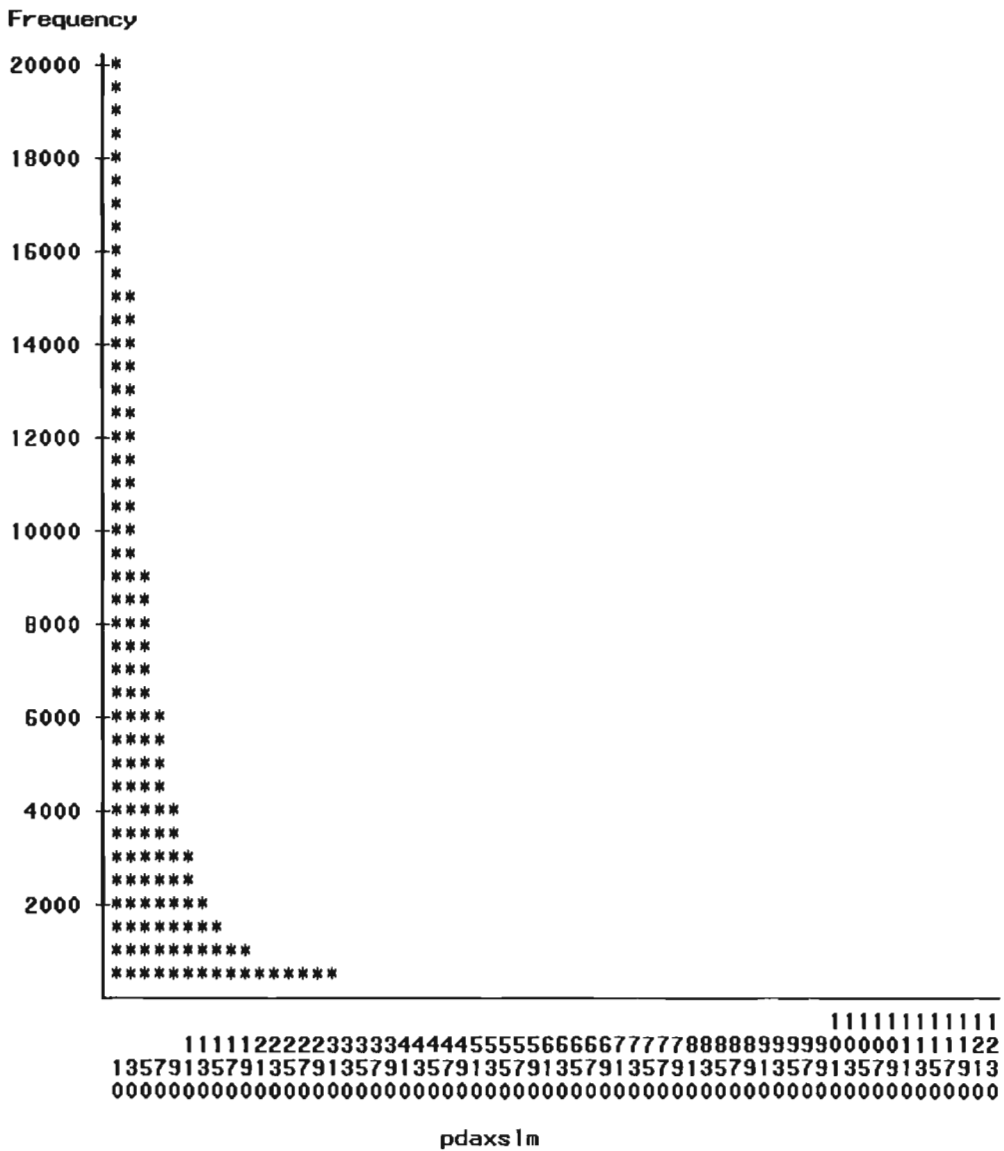
Variable Full Name: Peak*Duration Absolute Dynamic Y Force (N)
Abbreviated Name: pdadyf



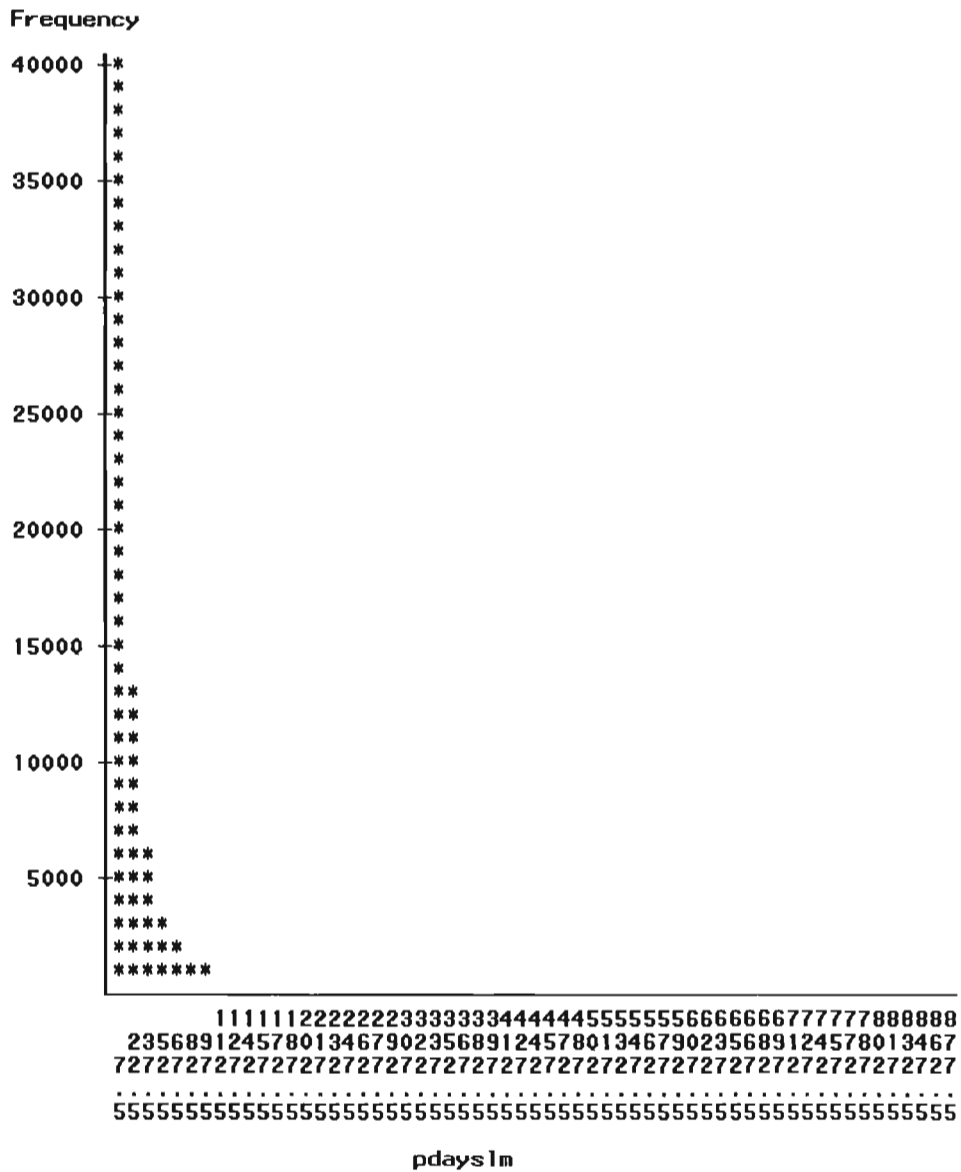
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Abbreviated Name: pdadyzf



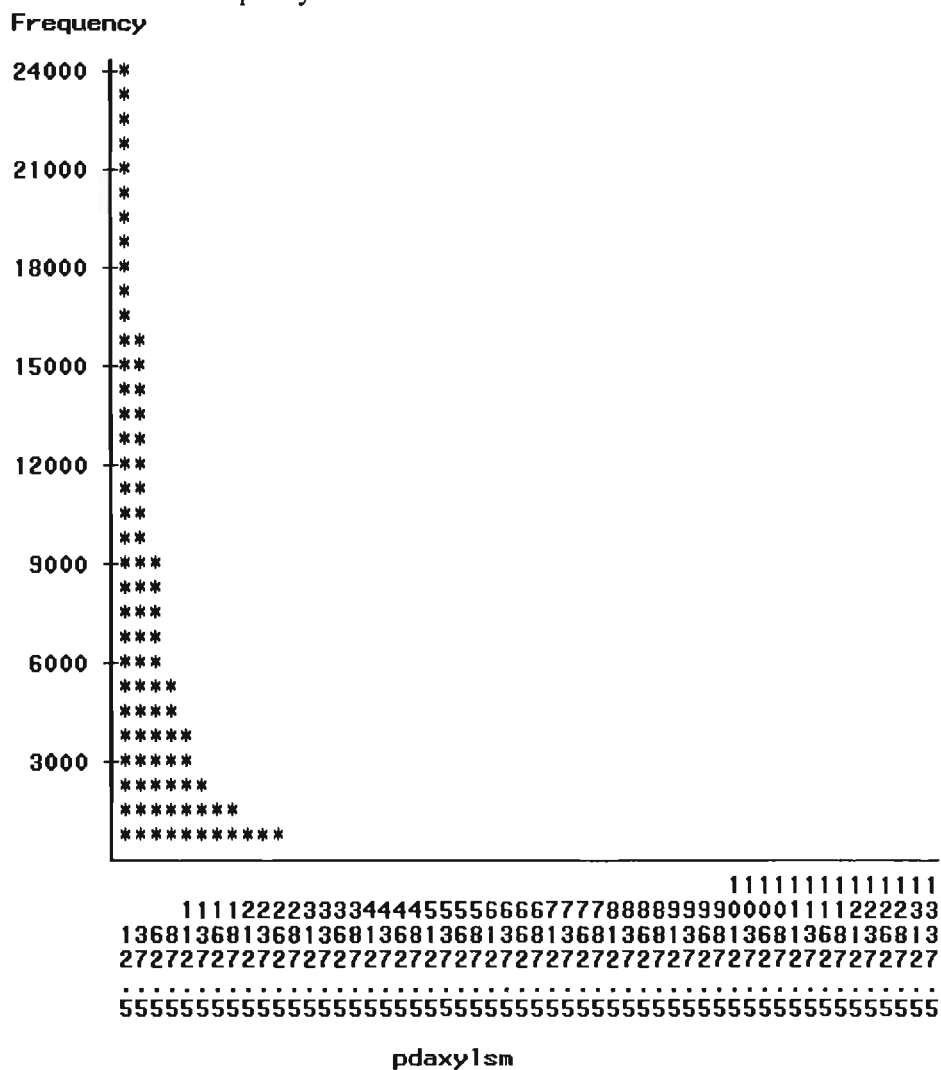
Variable Full Name: Peak*Duration Absolute X-axis Static Lift Moment (N*m)
Abbreviated Name: pdaxslm



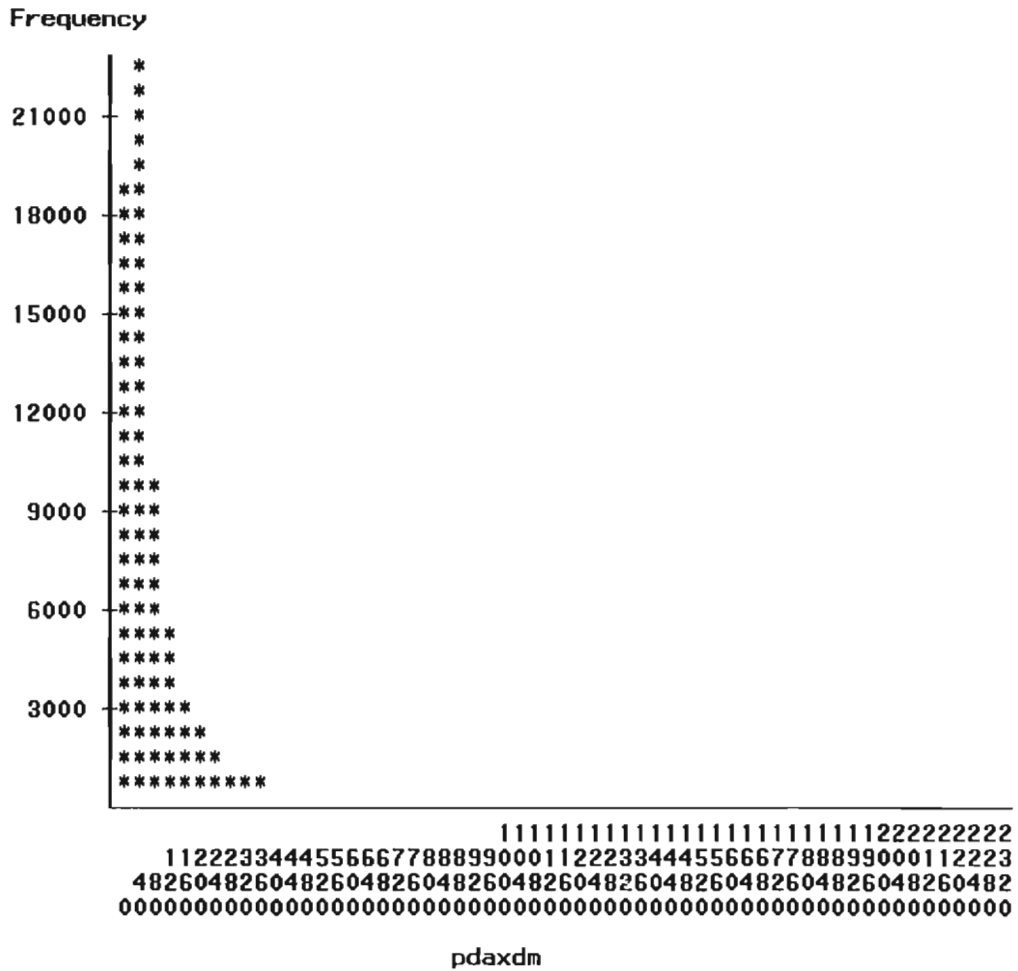
Variable Full Name: Peak*Duration Absolute Y-axis Static Lift Moment (N*m)
Abbreviated Name: pdayslm



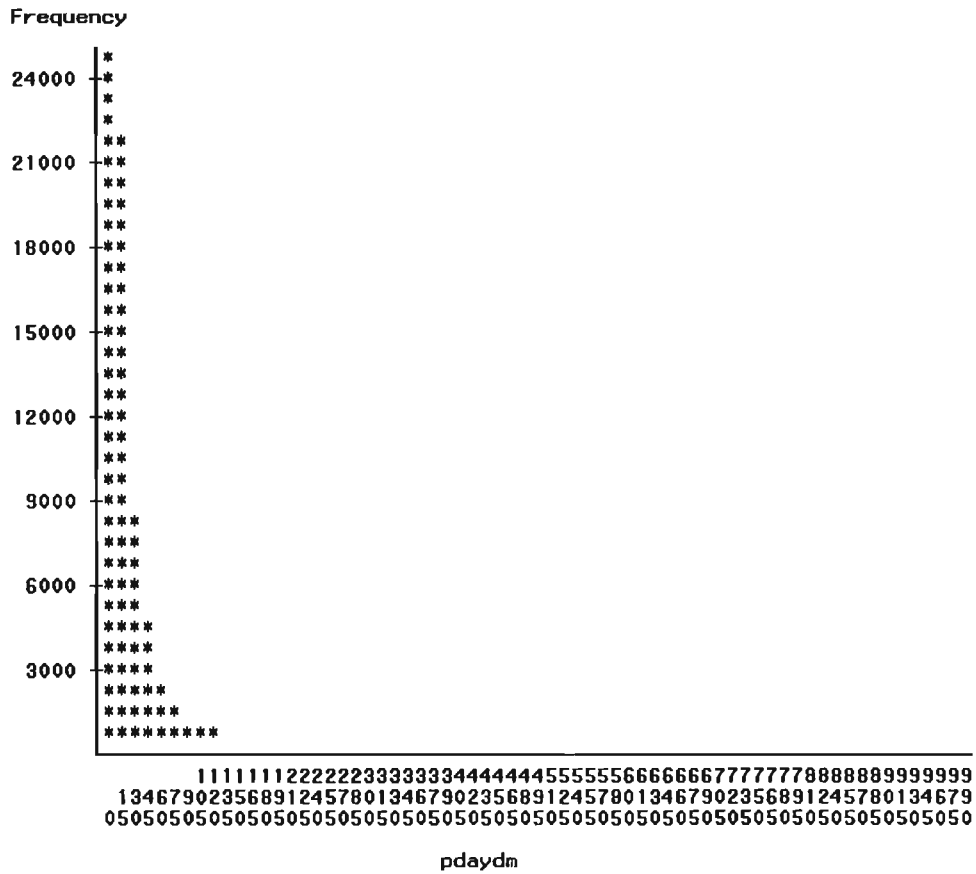
Abbreviated Name: pdaxylsm



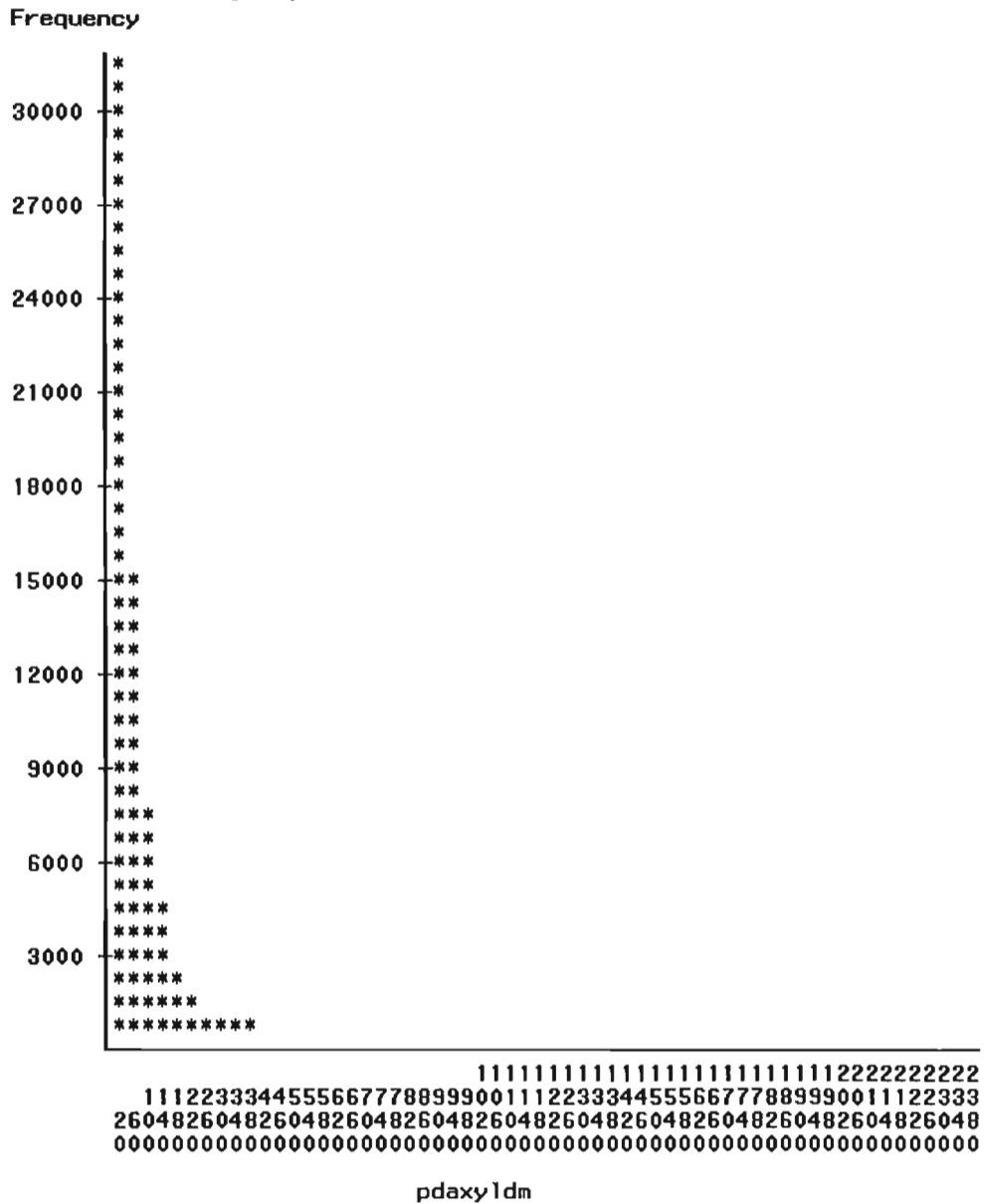
Variable Full Name: Peak*Duration Absolute X-axis Dynamic Moment (N*m)
Abbreviated Name: pdaxdm



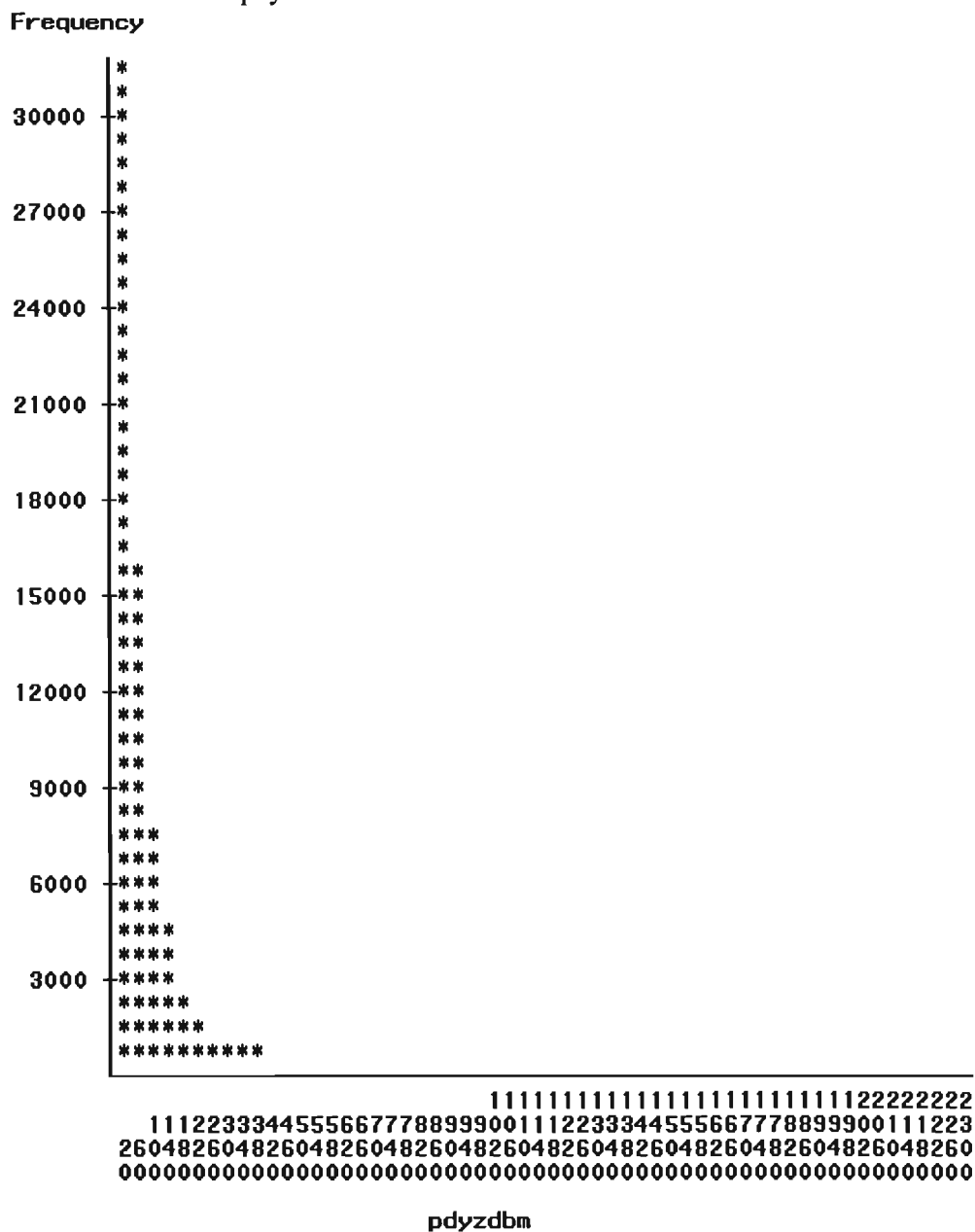
Variable Full Name: Peak*Duration Absolute Y-axis Dynamic Moment (N*m)
Abbreviated Name: pdaydm



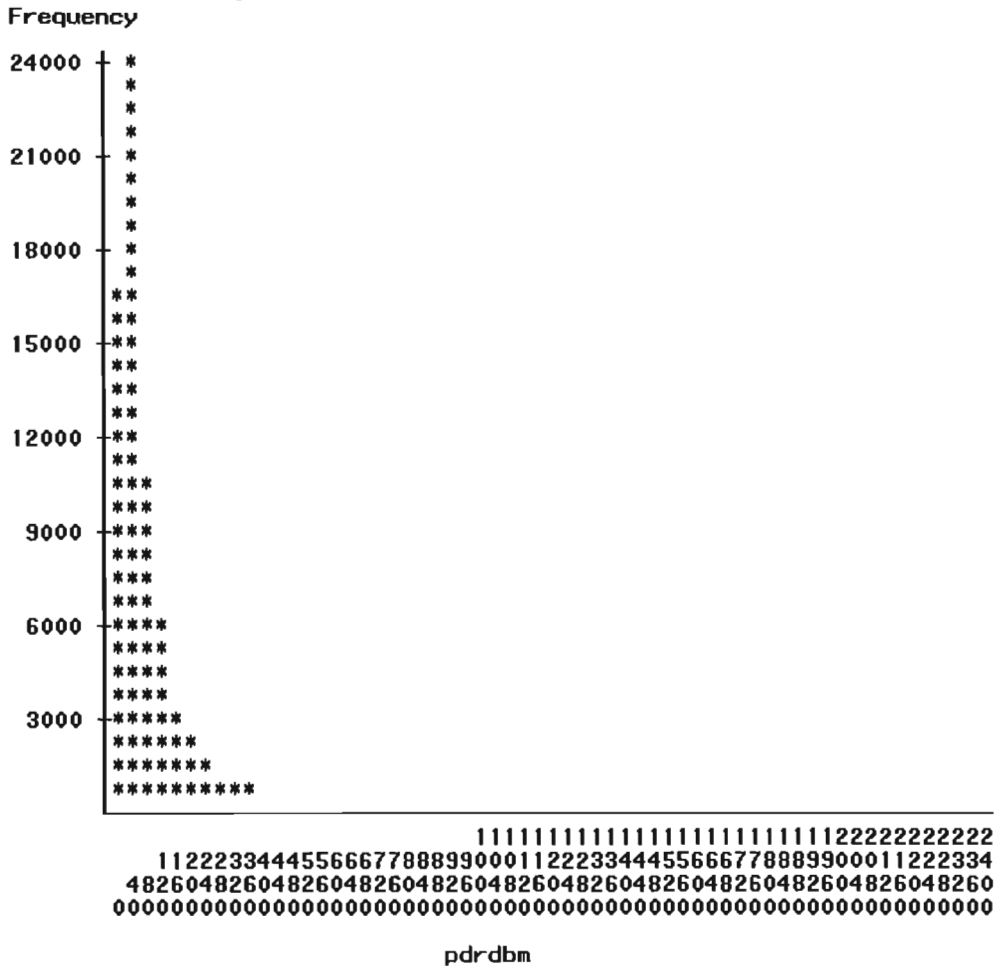
Variable Full Name: Peak*Duration Absolute XY*Lift Dynamic Moment (N*m)
Abbreviated Name: pdaxyldm



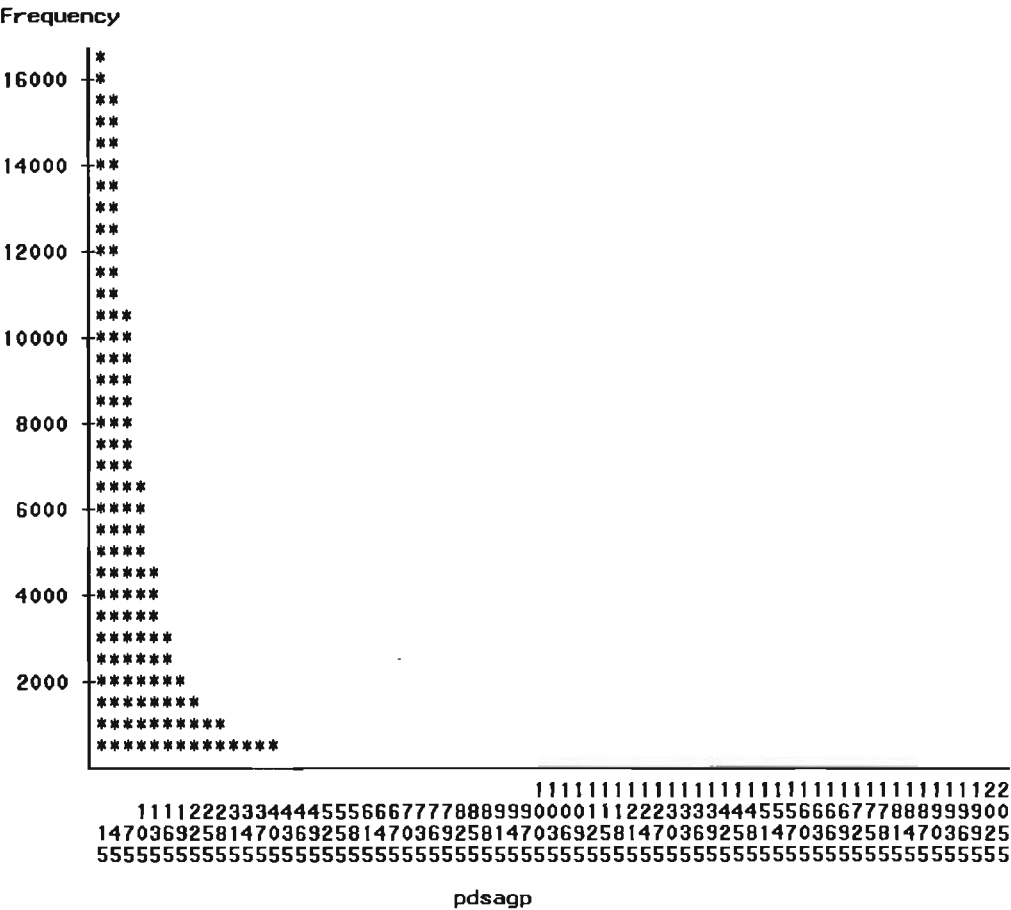
Abbreviated Name: pdyzdbm



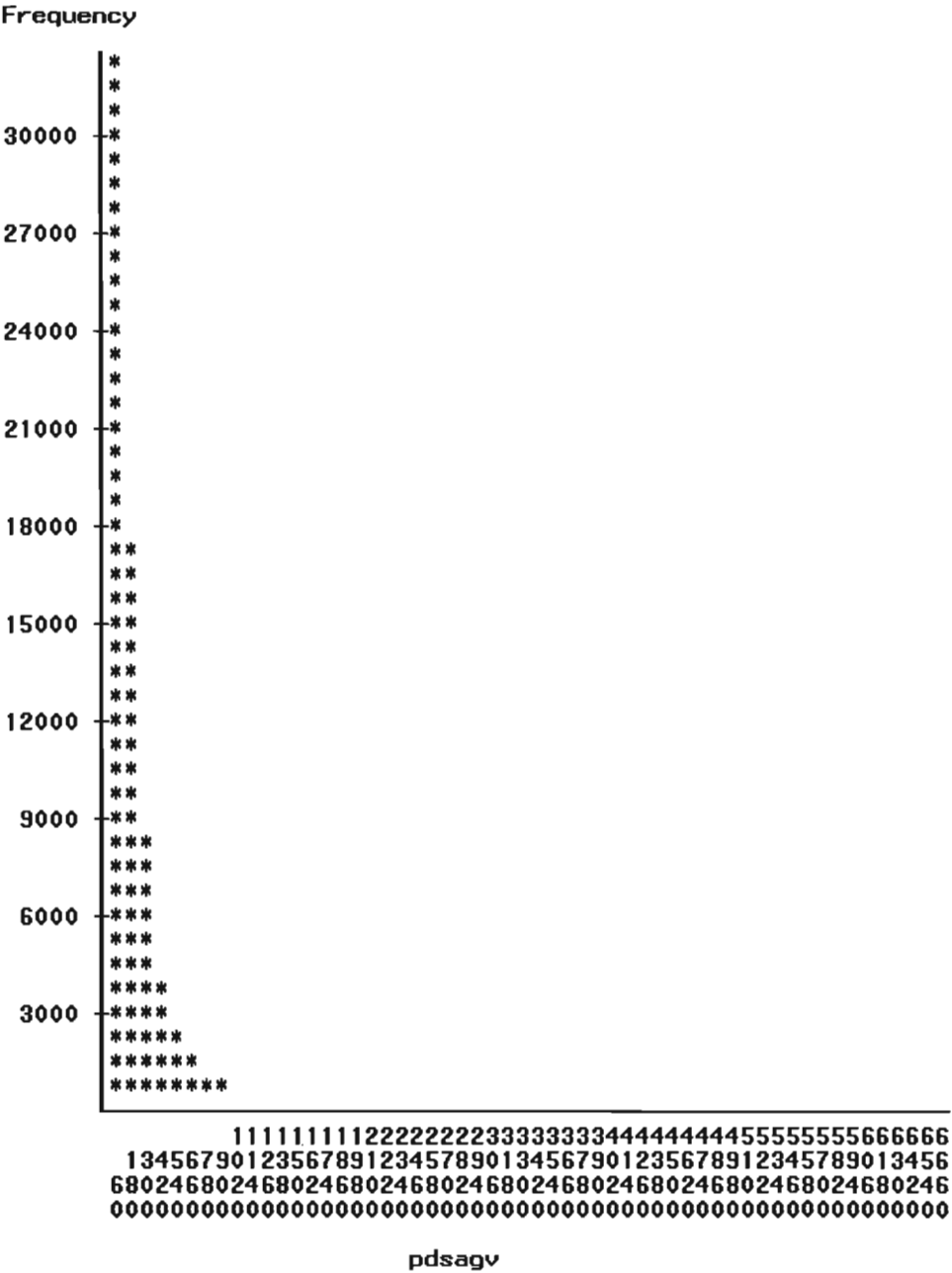
Variable Full Name: Peak*Duration Resultant Dynamic Moment (N*m)
Abbreviated Name: pdrdbm



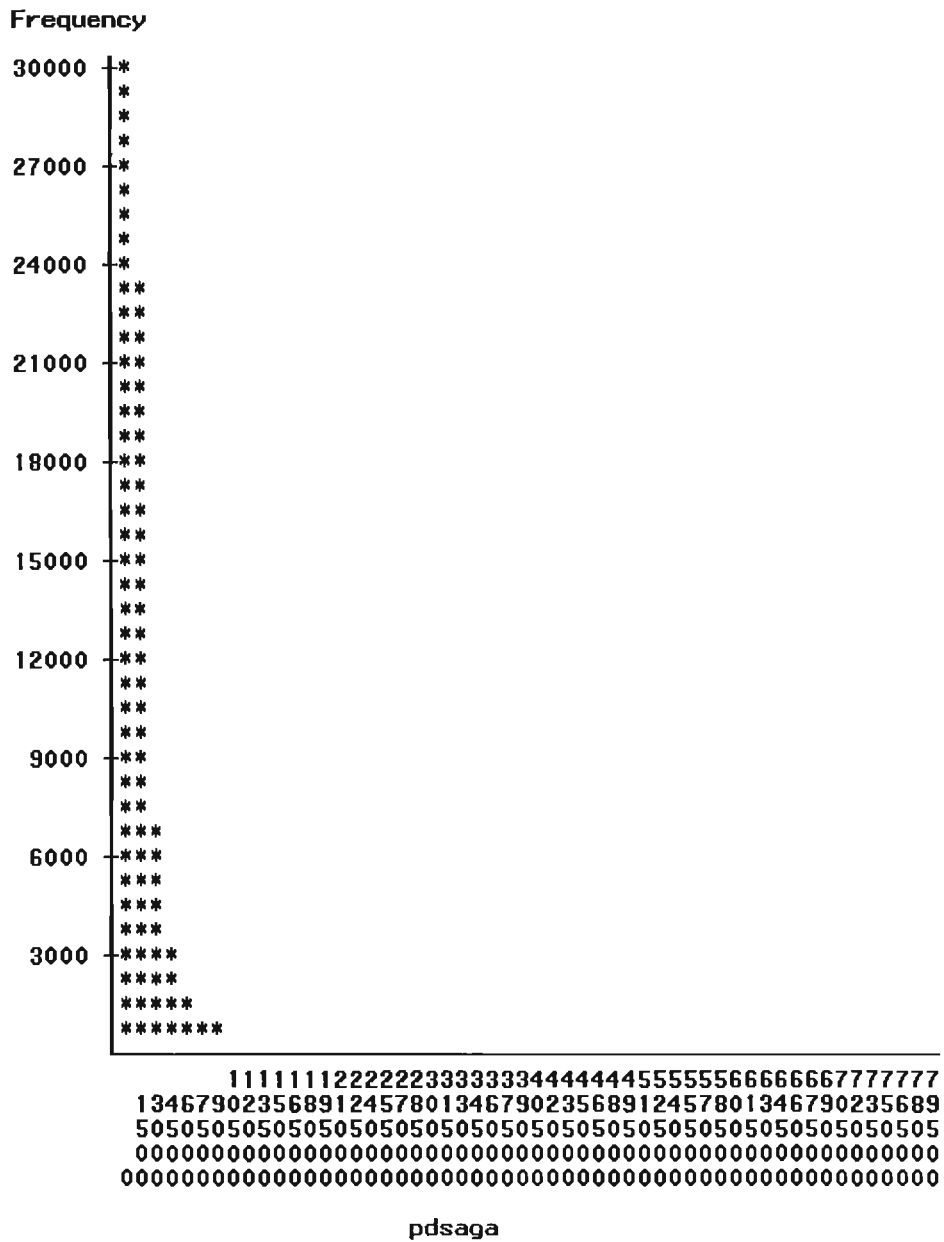
Variable Full Name: Peak*Duration Sagittal Trunk Angle (Degrees)
Abbreviated Name: pdsagp



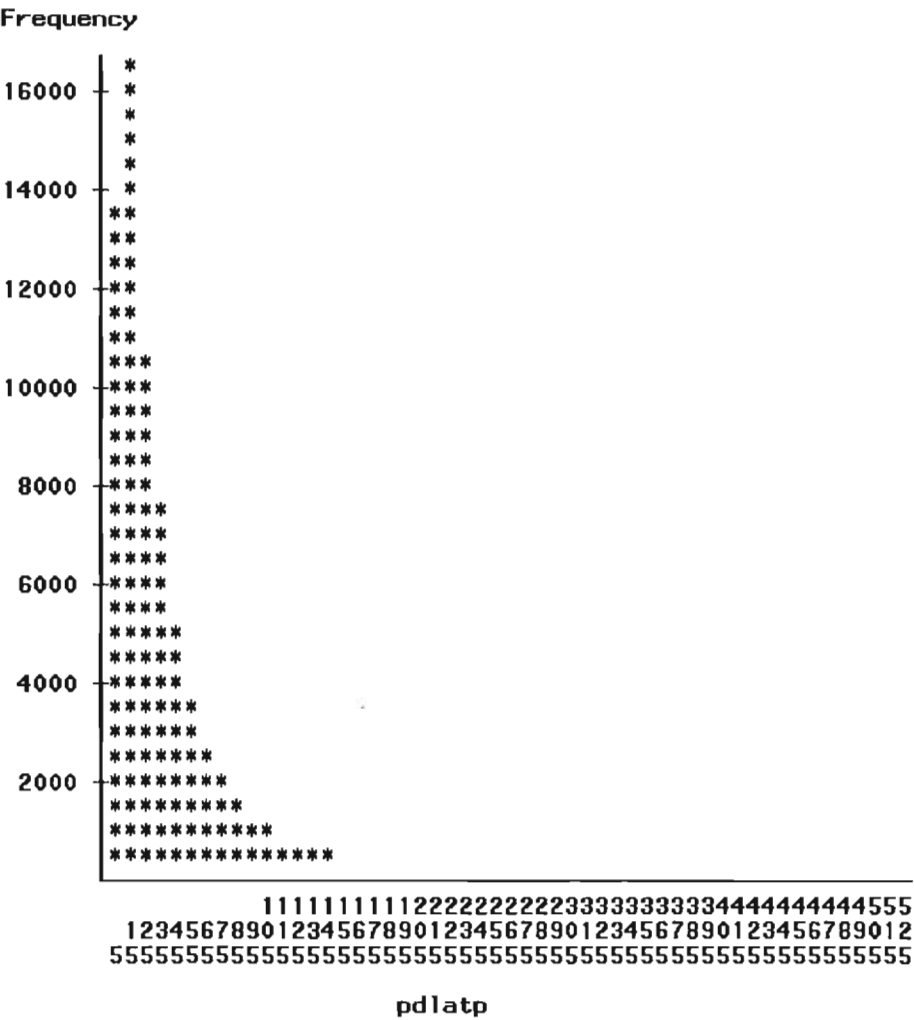
Variable Full Name: Peak*Duration Sagittal Velocity (Degrees/s)
Abbreviated Name: pdsagv



Variable Full Name: Peak*Duration Sagittal Acceleration (Degrees/s^2)
Abbreviated Name: pdsaga



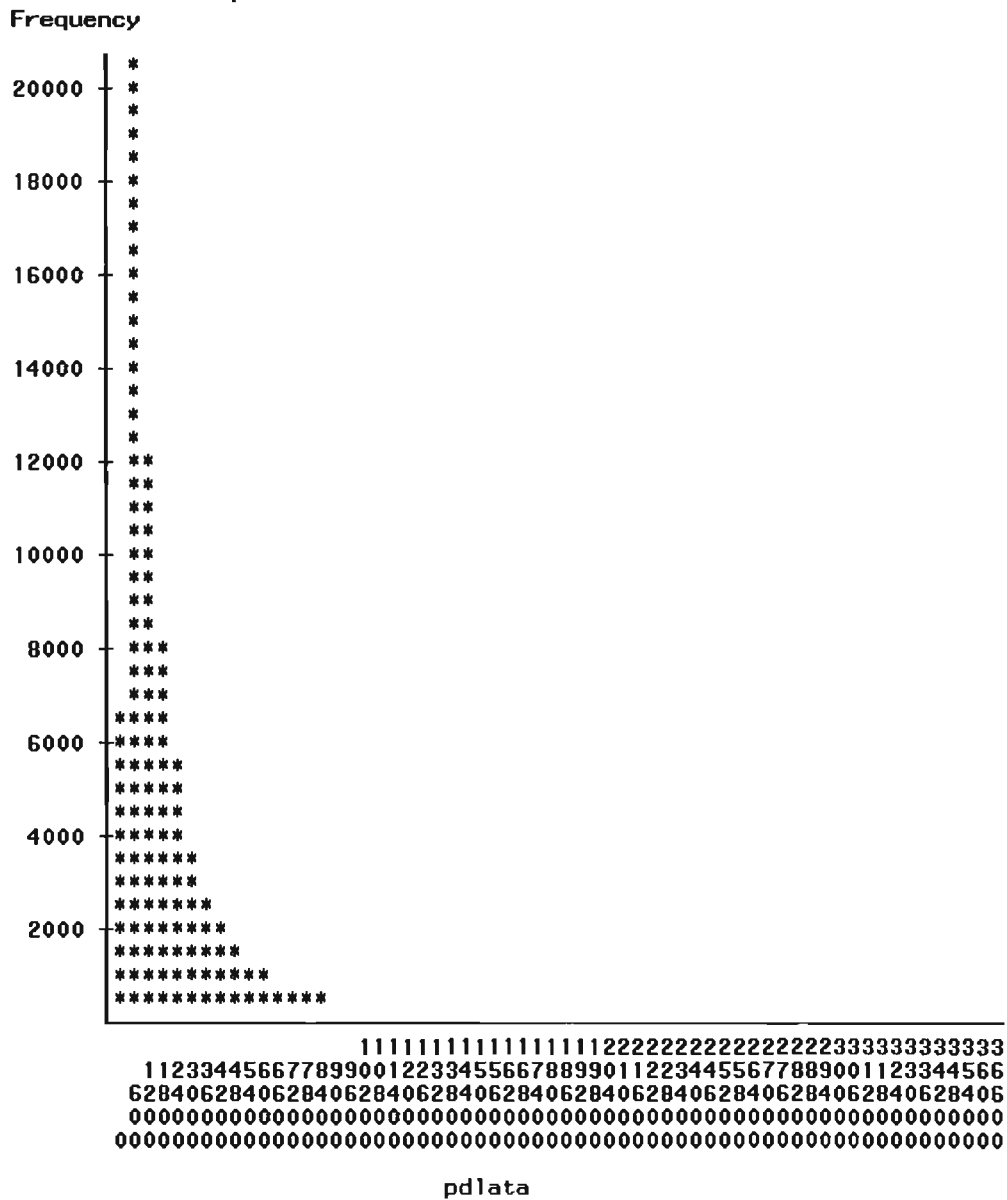
Variable Full Name: Peak*Duration Lateral Trunk Angle (Degrees)
Abbreviated Name: pdlatp



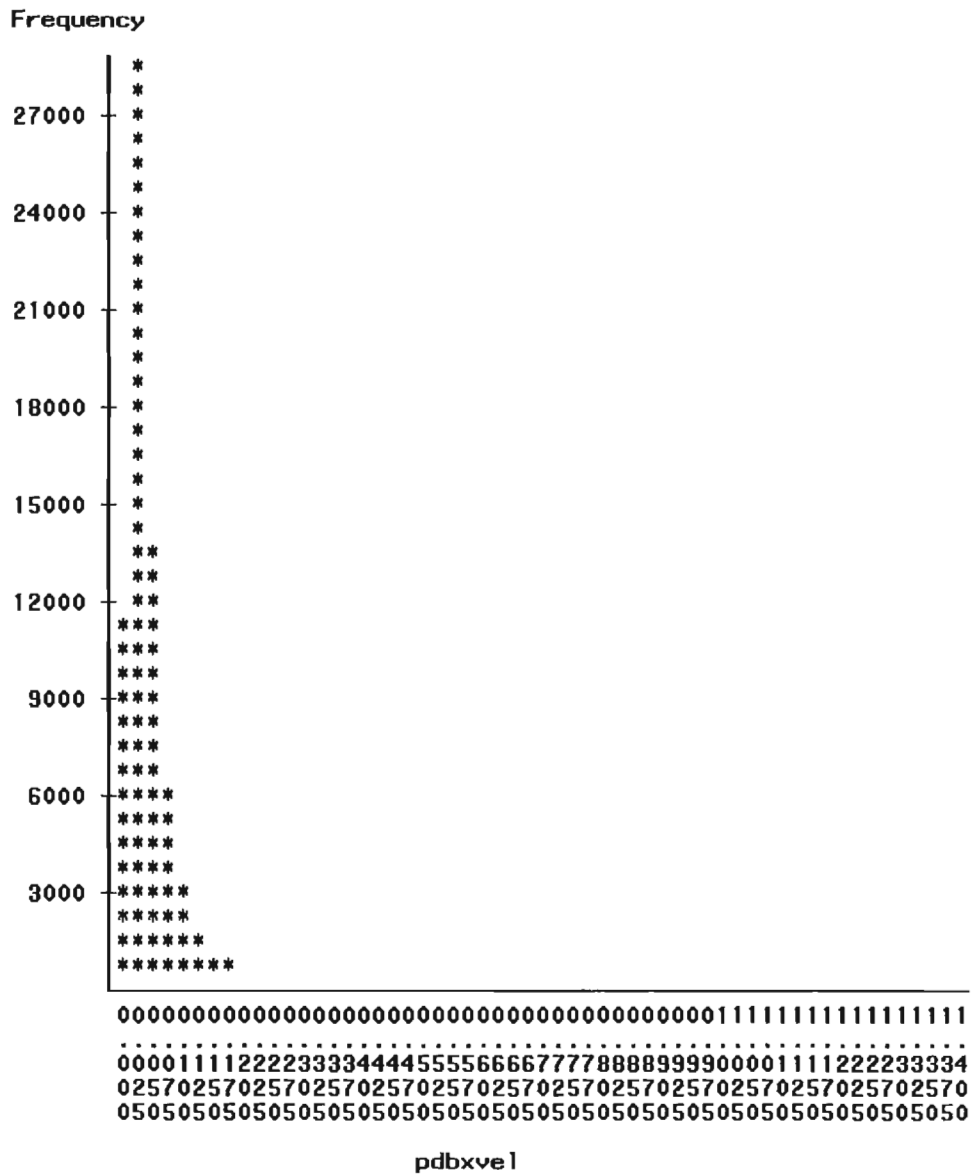
Abbreviated Name: pdlatv



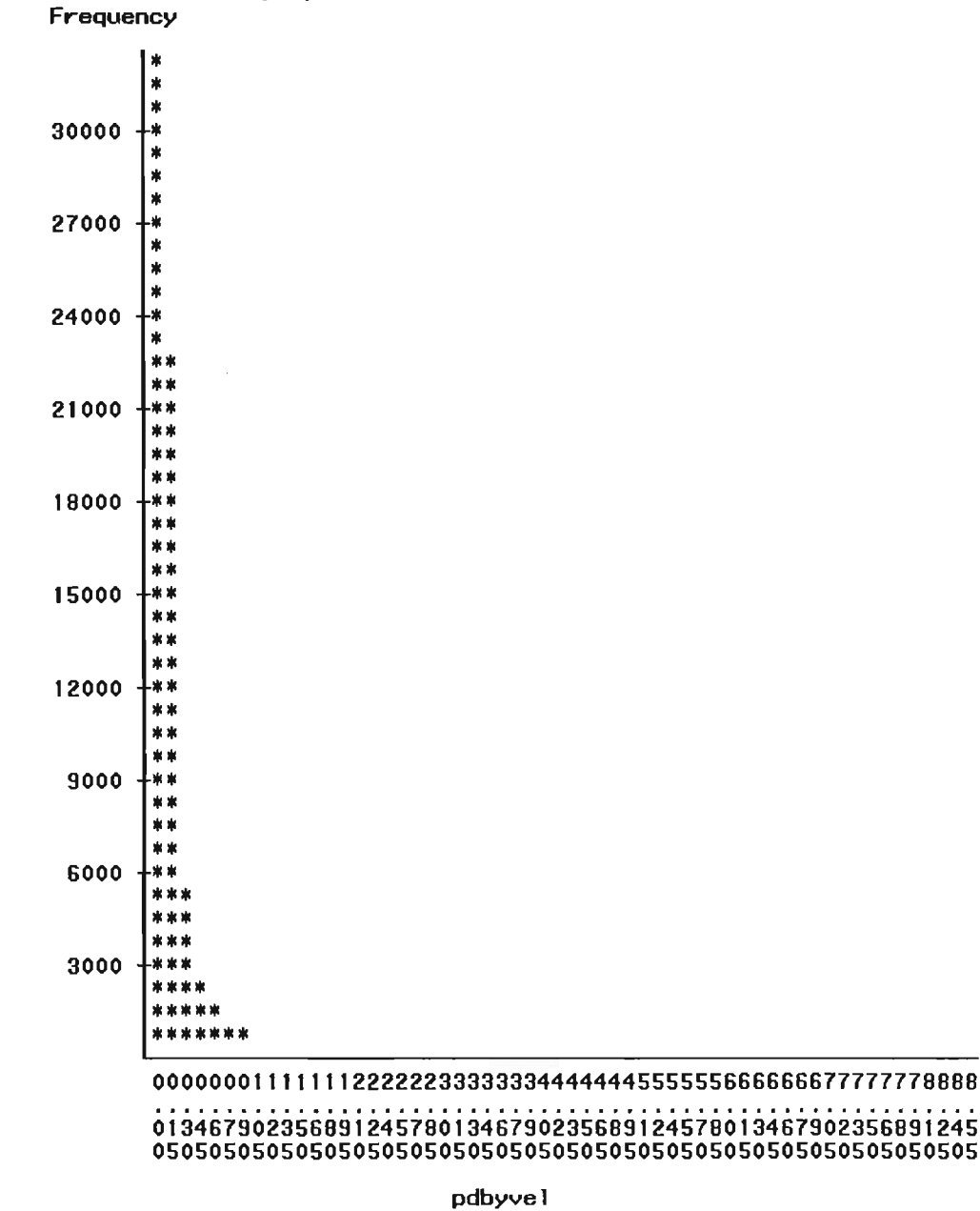
Variable Full Name: Peak*Duration Lateral Acceleration (Degrees/s^2)
Abbreviated Name: pdlata



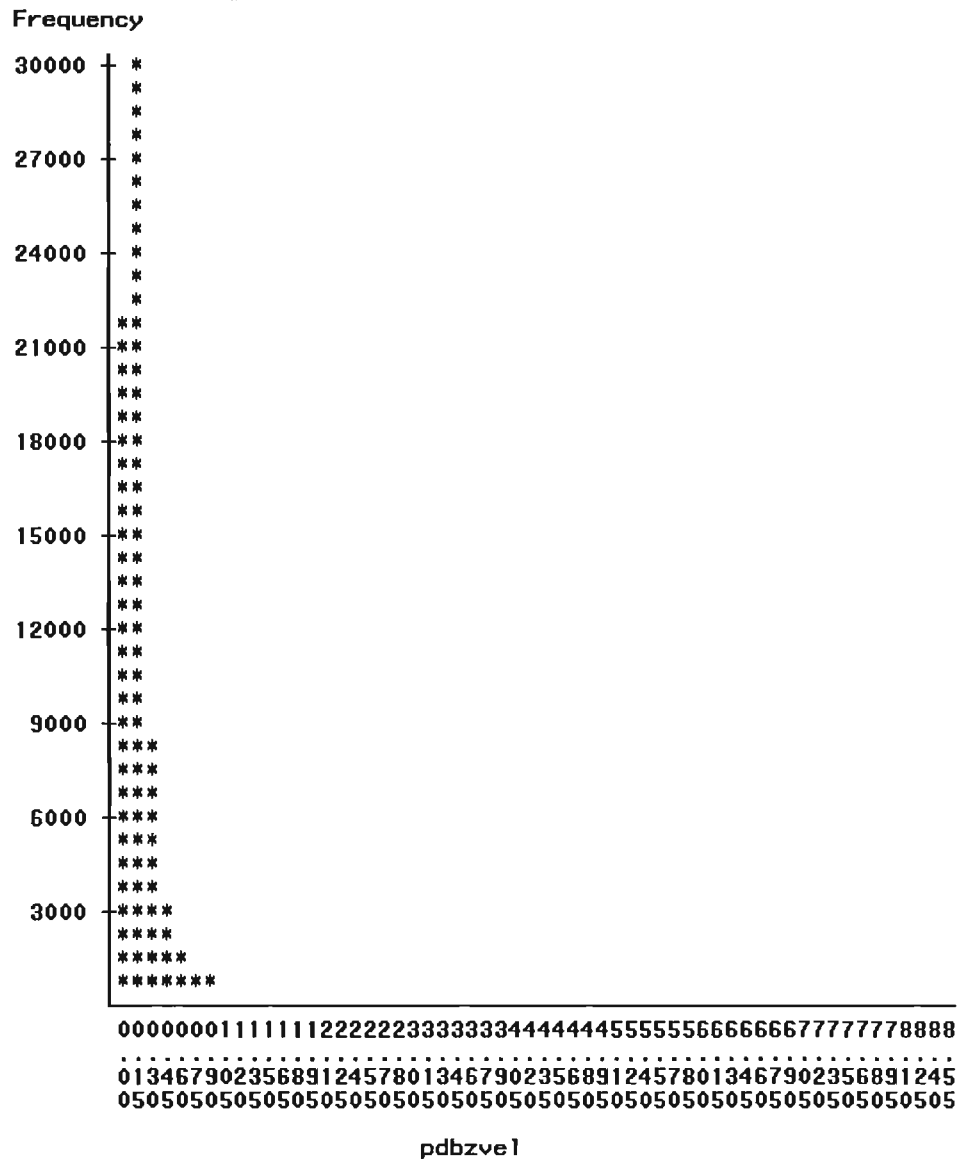
Variable Full Name: Peak*Duration Box X Velocity (m/s)
Abbreviated Name: pdbxvel



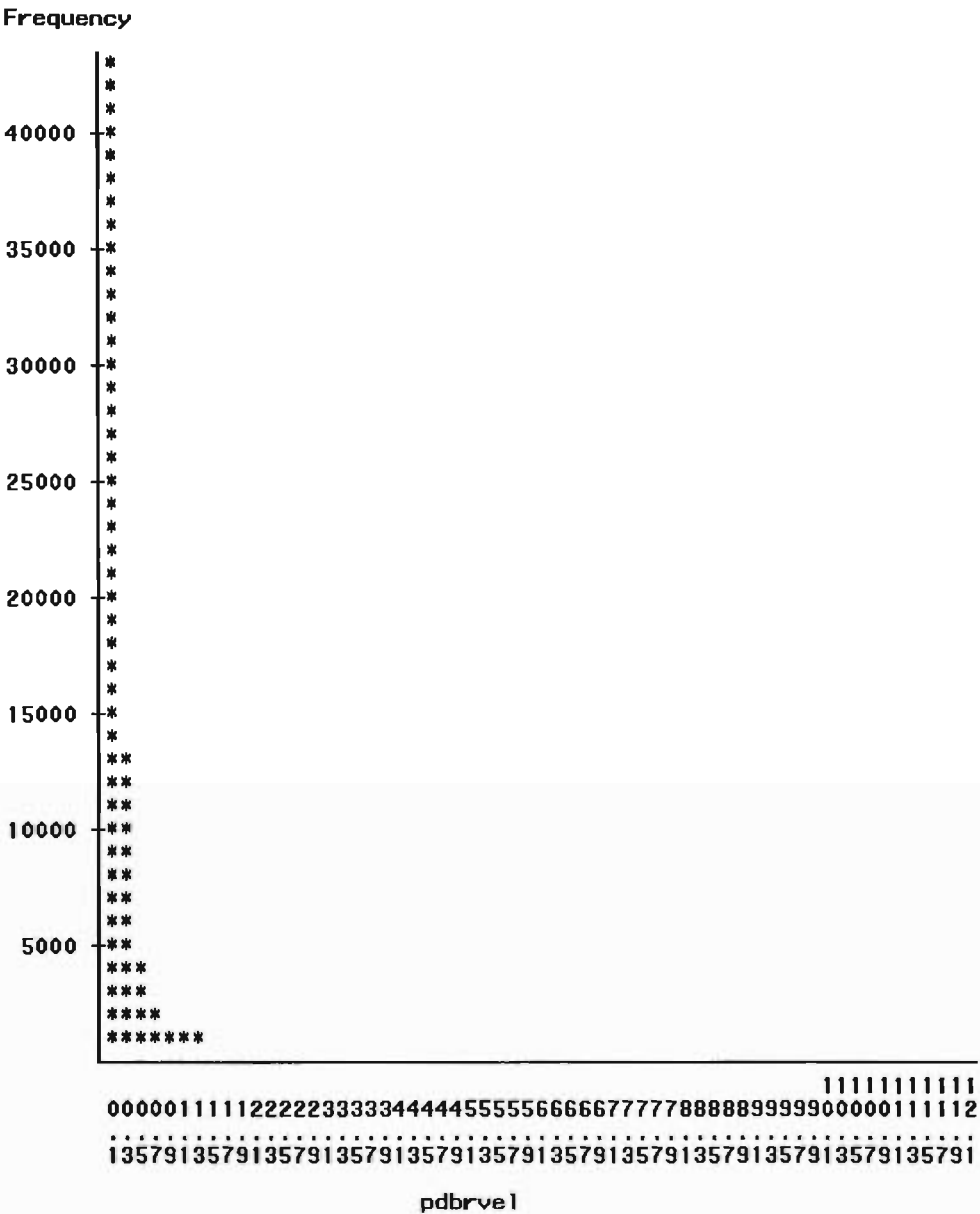
Variable Full Name: Peak*Duration Box Y Velocity (m/s)
Abbreviated Name: pdbyvel



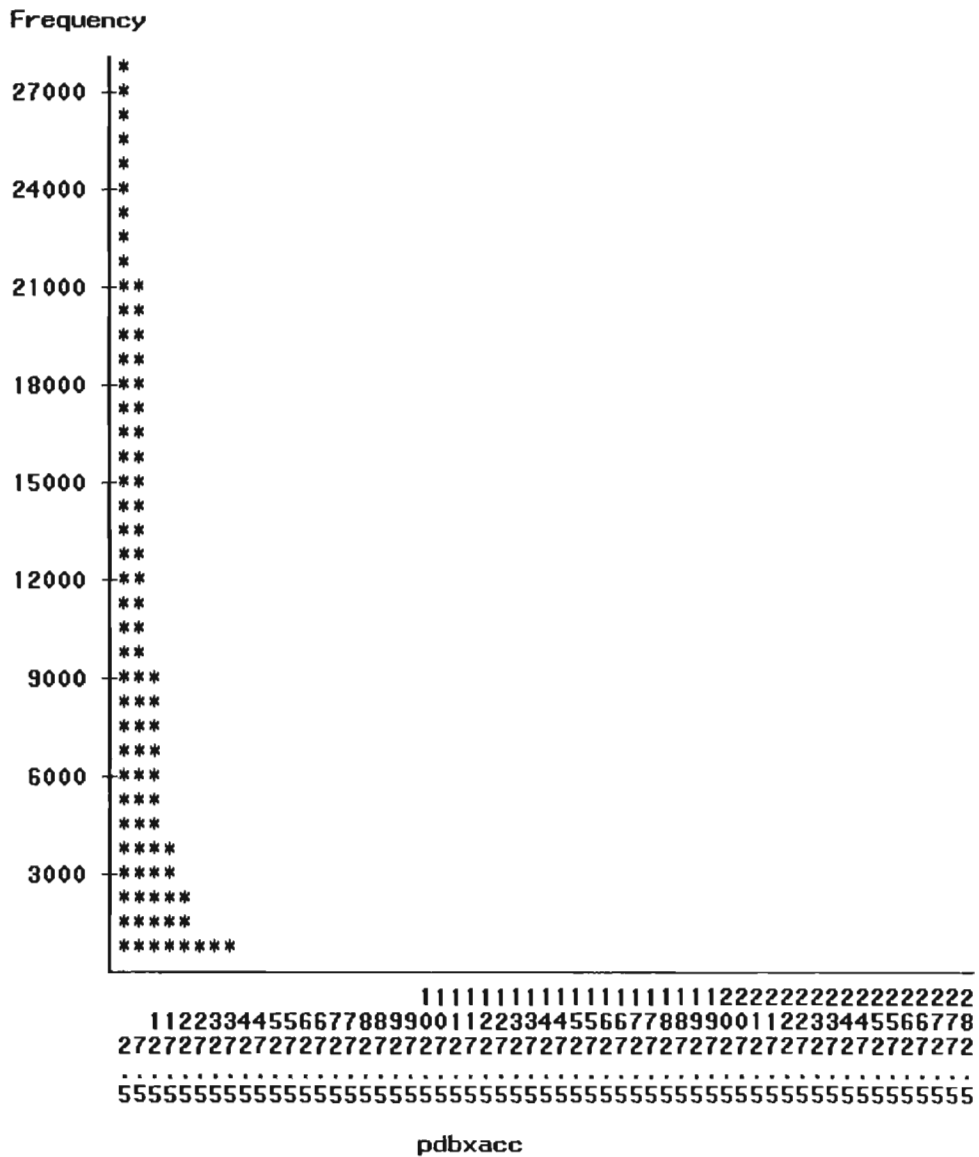
Variable Full Name: Peak*Duration Box Z Velocity (m/s)
Abbreviated Name: pdbzvel



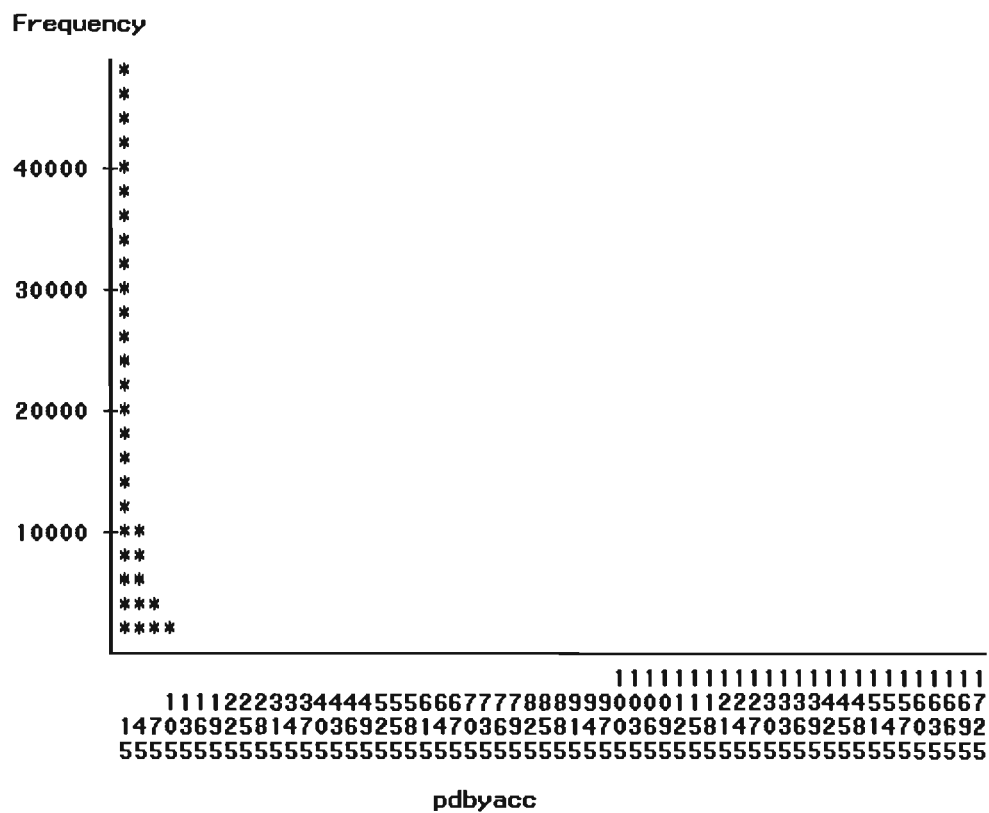
Variable Full Name: Peak*Duration Box Resultant Velocity (m/s)
Abbreviated Name: pdrbrvel



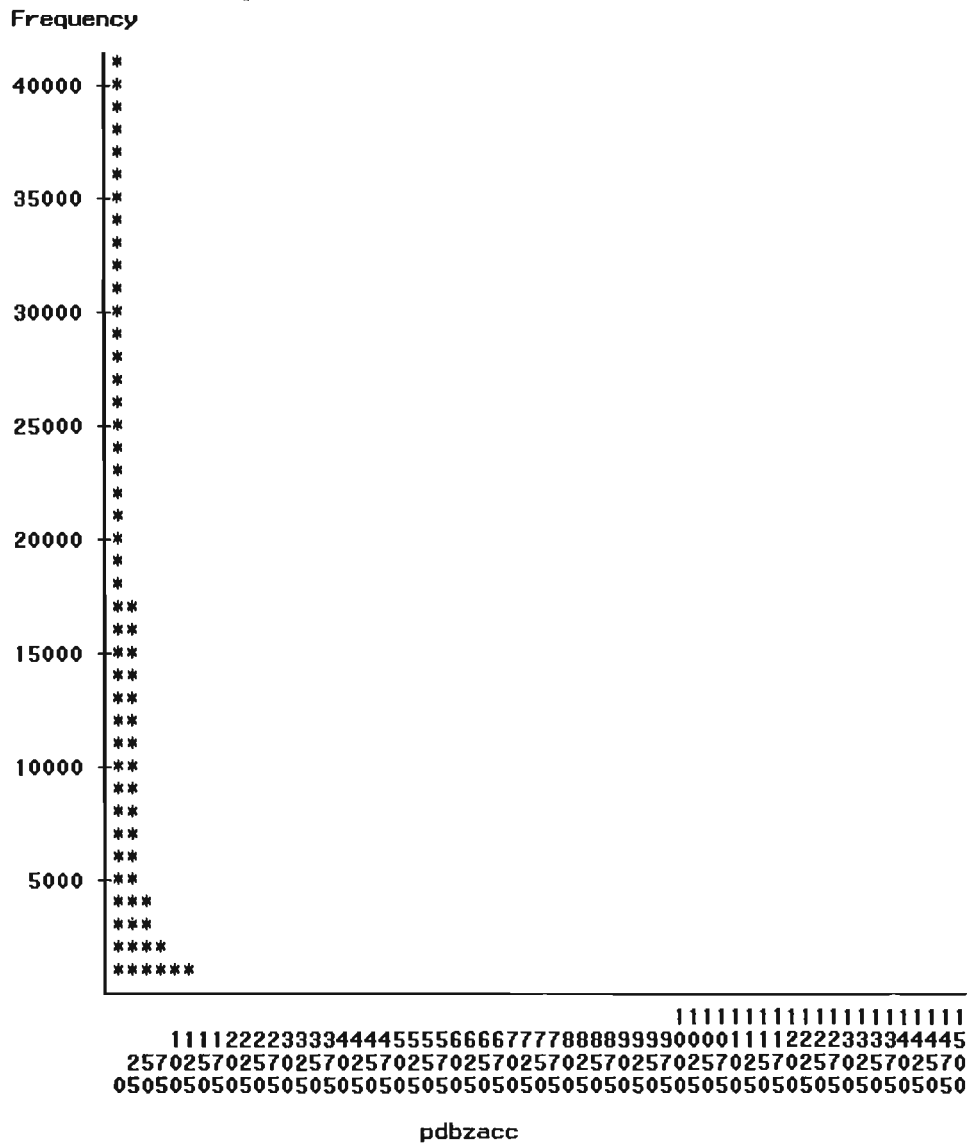
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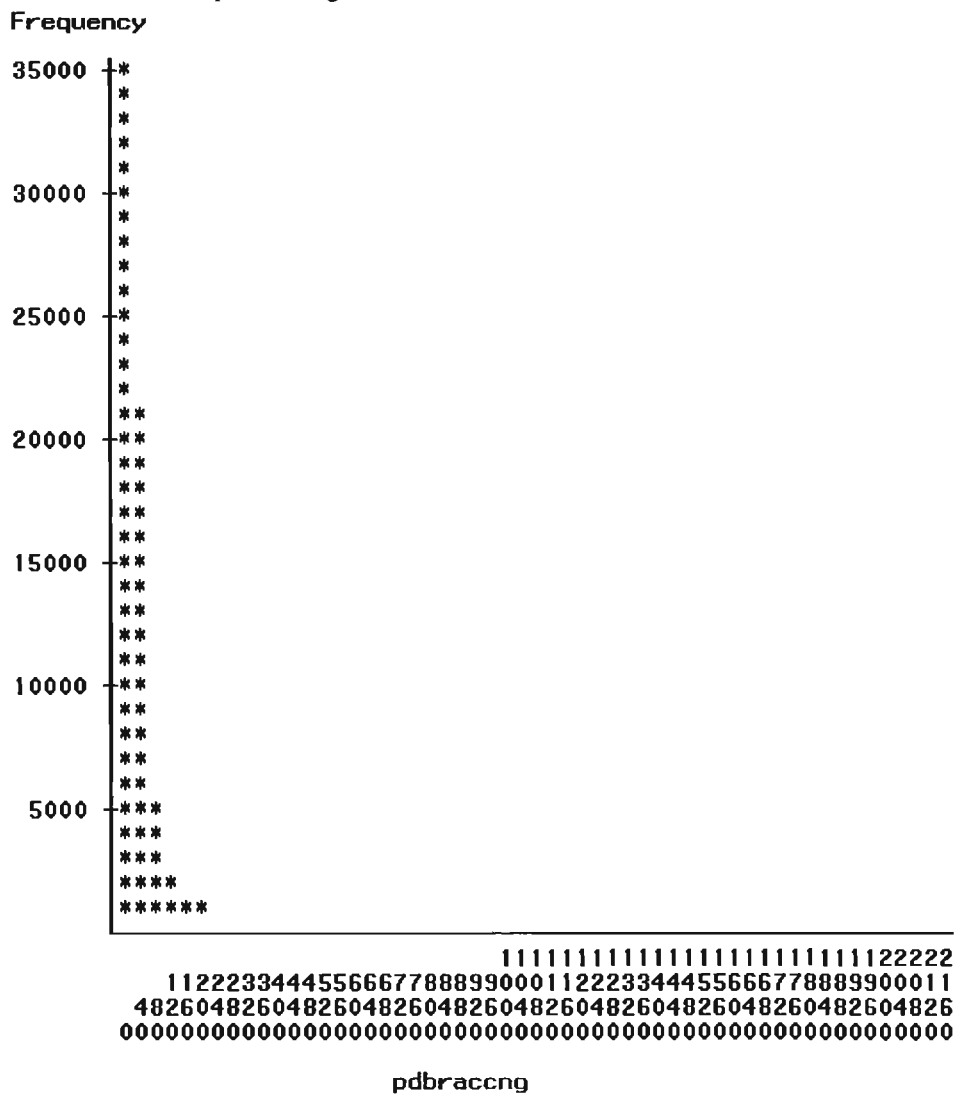
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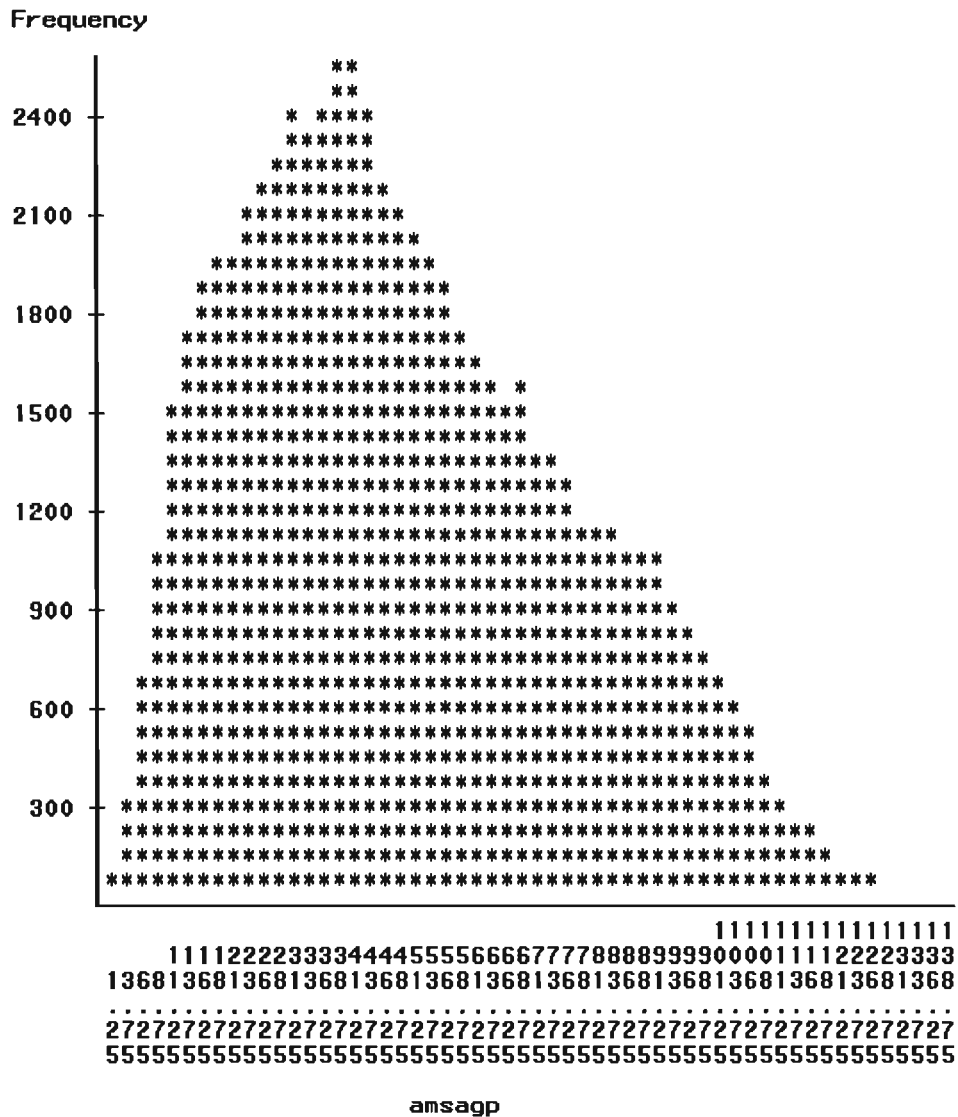
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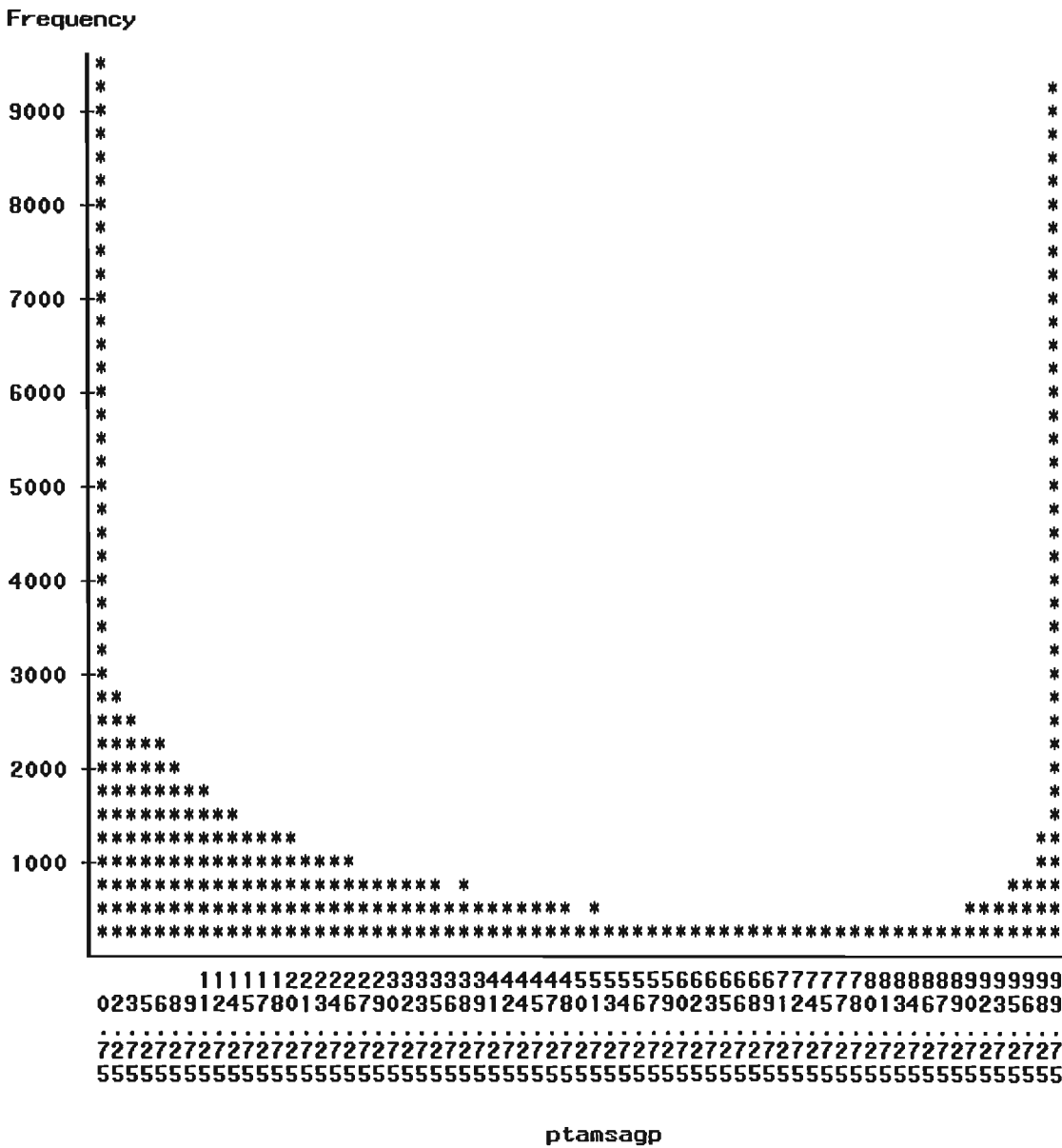
Abbreviated Name: pdbraccng



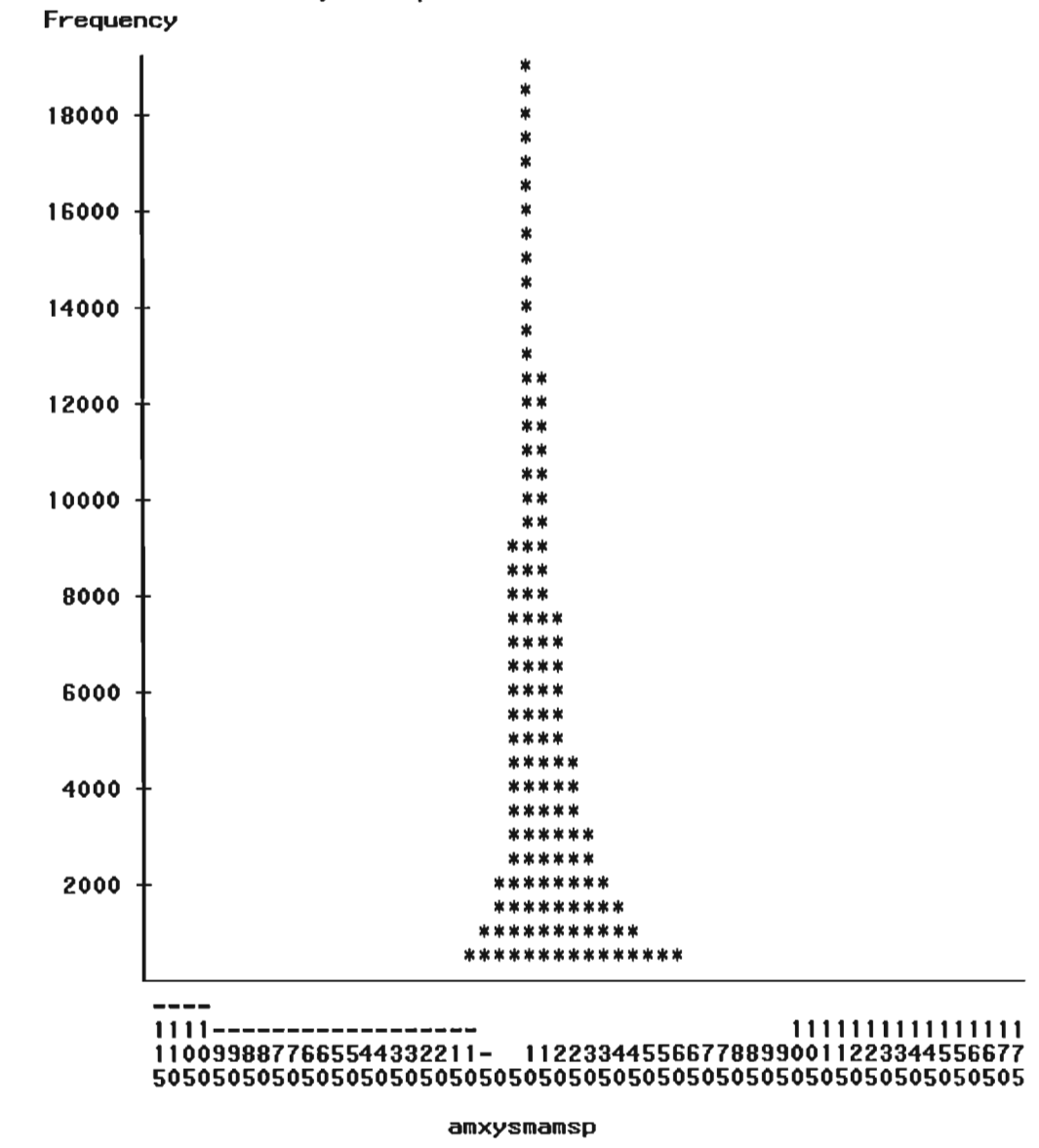
Variable Full Name: Absolute Maximum Sagittal Trunk Angle (Degrees)
Abbreviated Name: amsagp



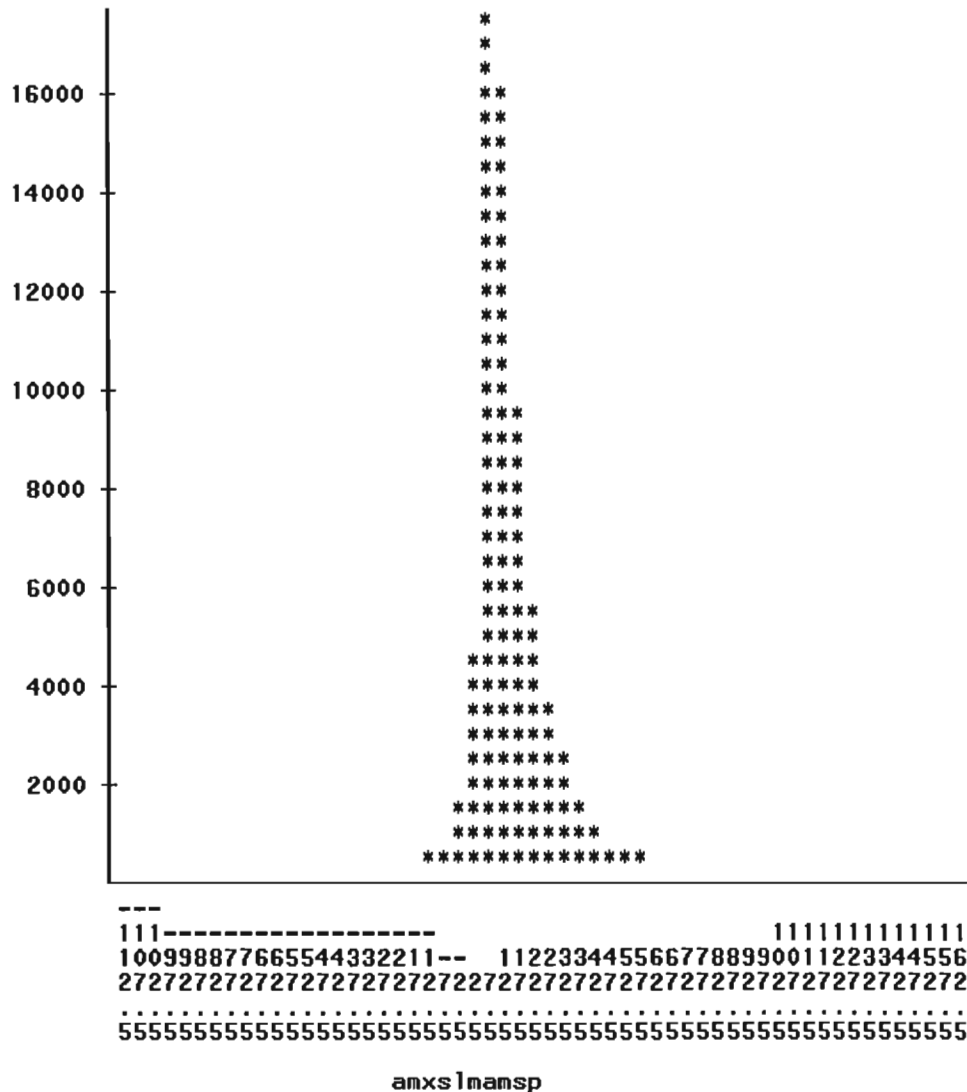
Variable Full Name: Percent Time of Absolute Maximum Sagittal Trunk Angle (%)
Abbreviated Name: ptamsagp



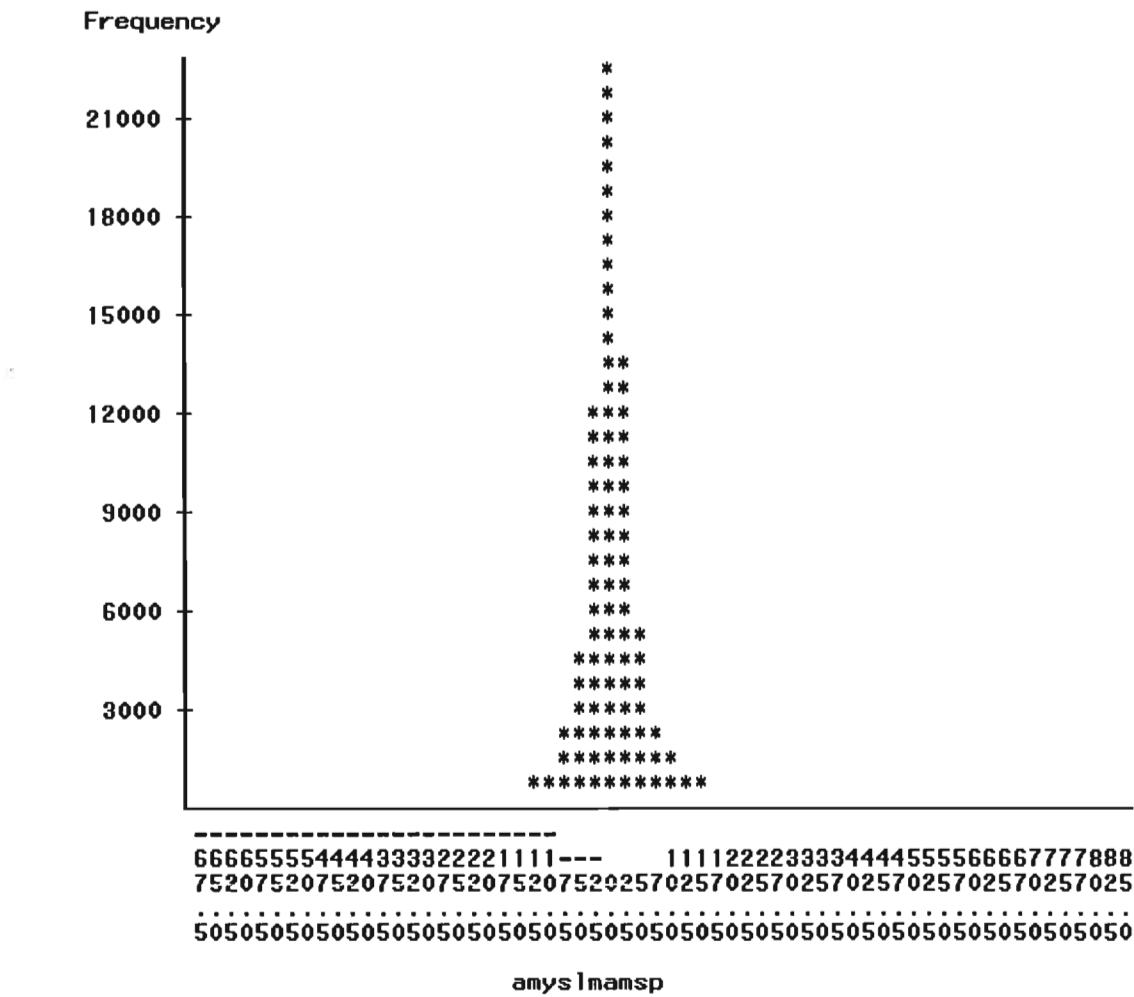
Variable Full Name: Absolute XY*Lift Static Moment at Absolute Maximum Sagittal
Trunk Angle (N*m)
Abbreviated Name: amxysmamsp



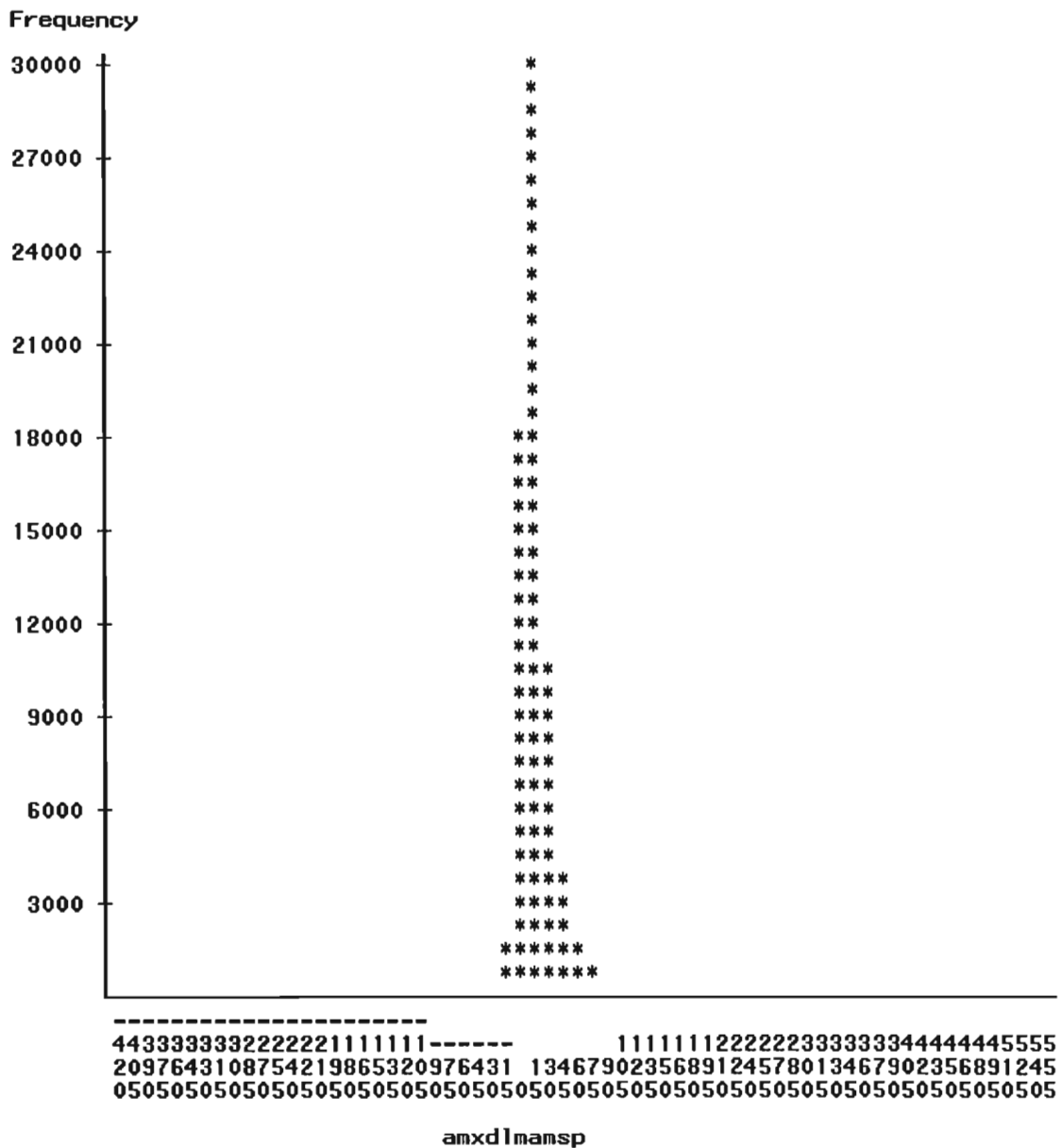
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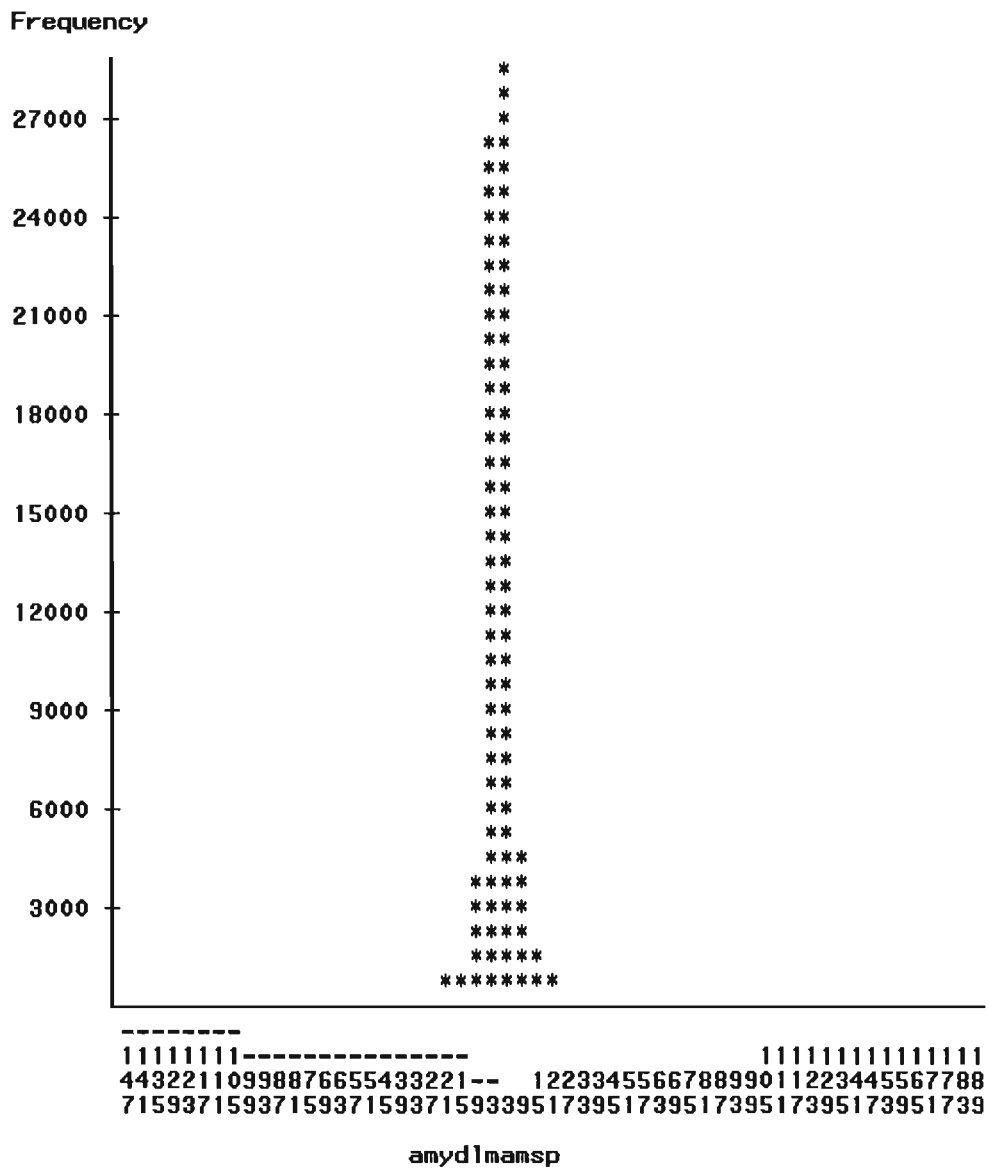
Variable Full Name: Absolute Y-axis Static Lift Moment at Absolute Maximum Sagittal Trunk Angle (N*m)
Abbreviated Name: amyslmanmsp



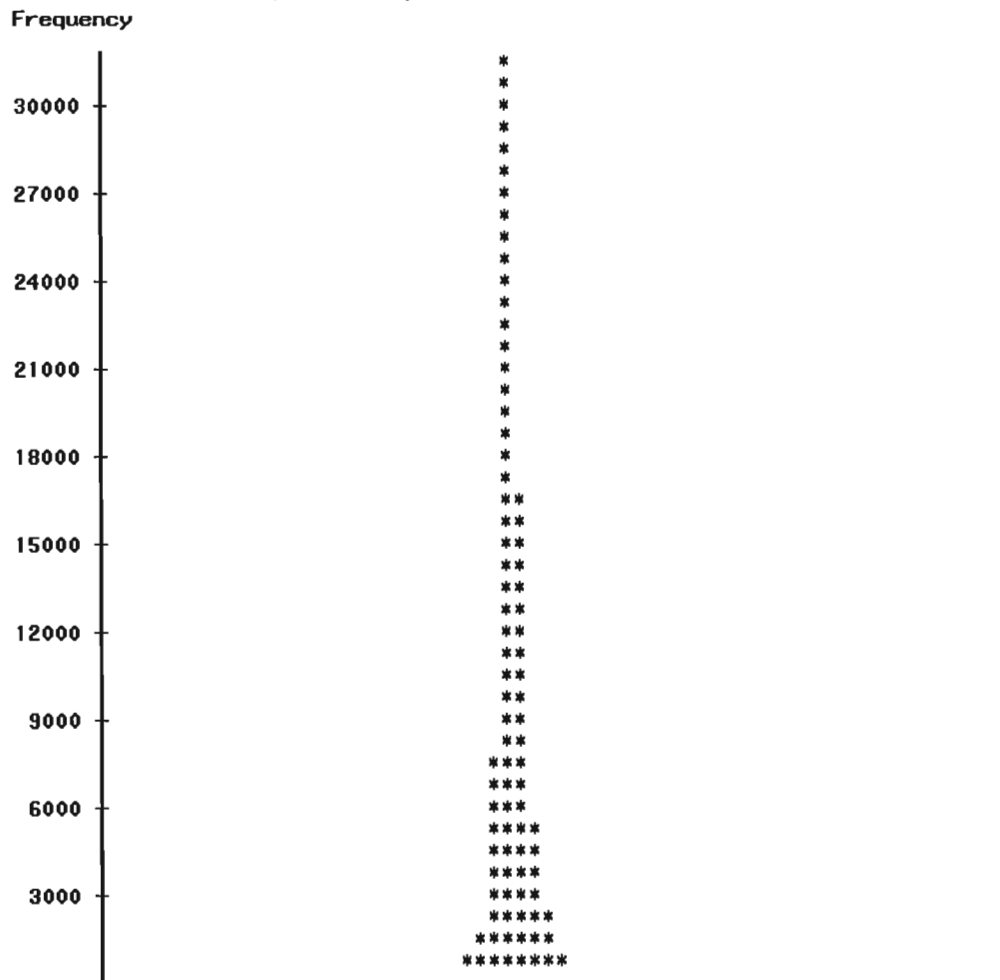
Variable Full Name: Absolute X-axis Dynamic Lift Moment at Absolute Maximum
Sagittal Trunk Angle (N*m)
Abbreviated Name: amxdlmamsp



Variable Full Name: Absolute Y-axis Dynamic Lift Moment at Absolute Maximum
Sagittal Trunk Angle (N*m)
Abbreviated Name: amydlmamp



Abbreviated Name: amyzdbmamsp

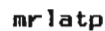
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amyzdbmamp

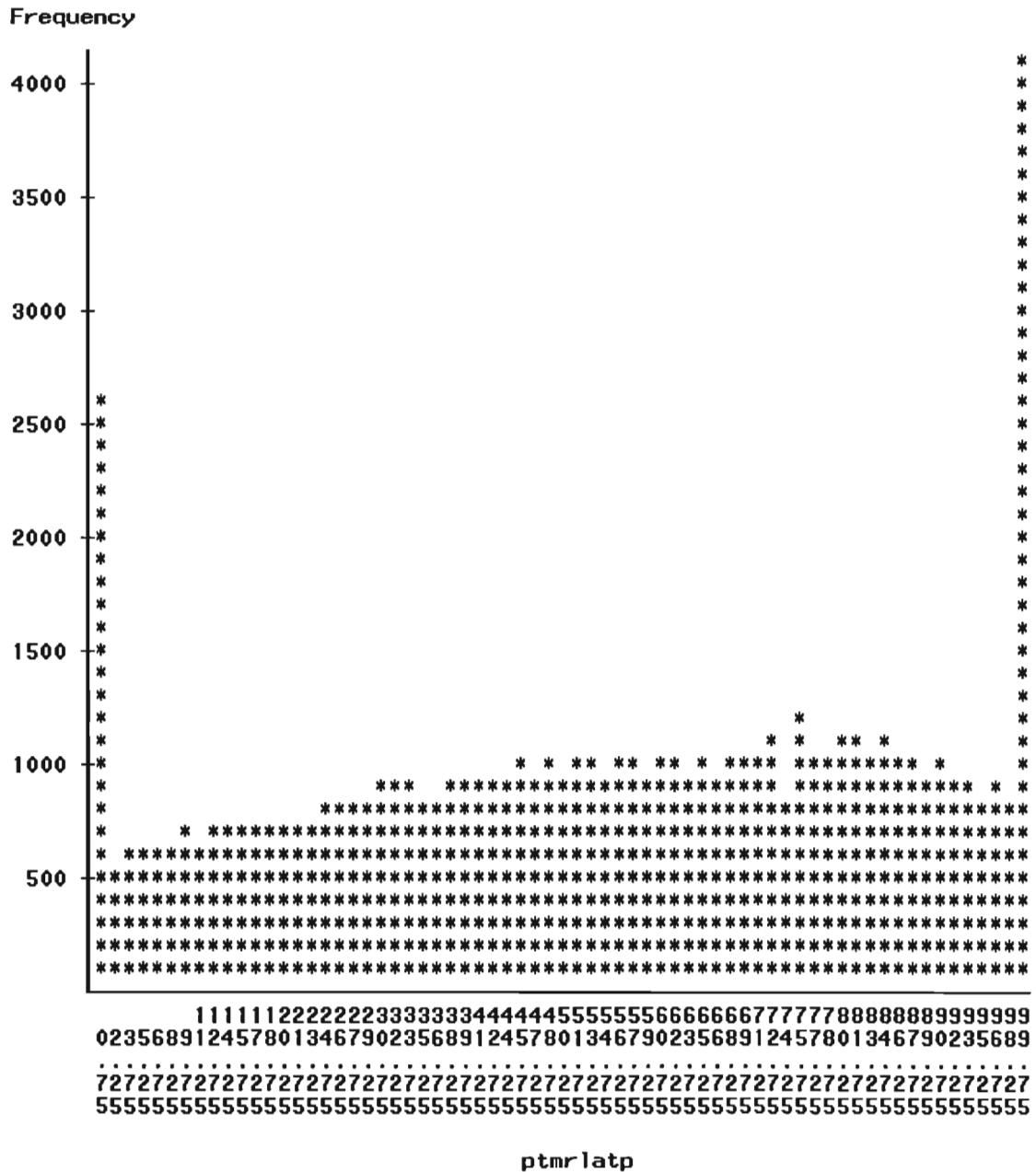
Abbreviated Name: amrmamsp



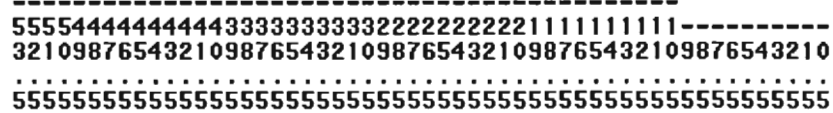
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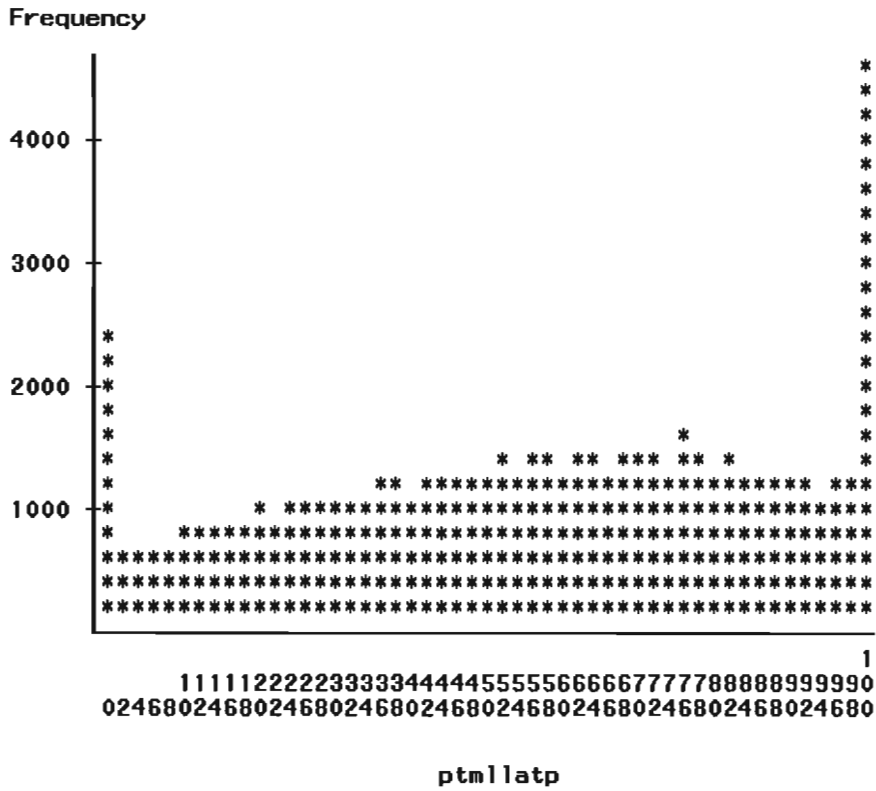
Variable Full Name: Percent Time of Maximum Right Lateral Trunk Angle (%)
Abbreviated Name: ptmrlatp



Abbreviated Name: mllatp

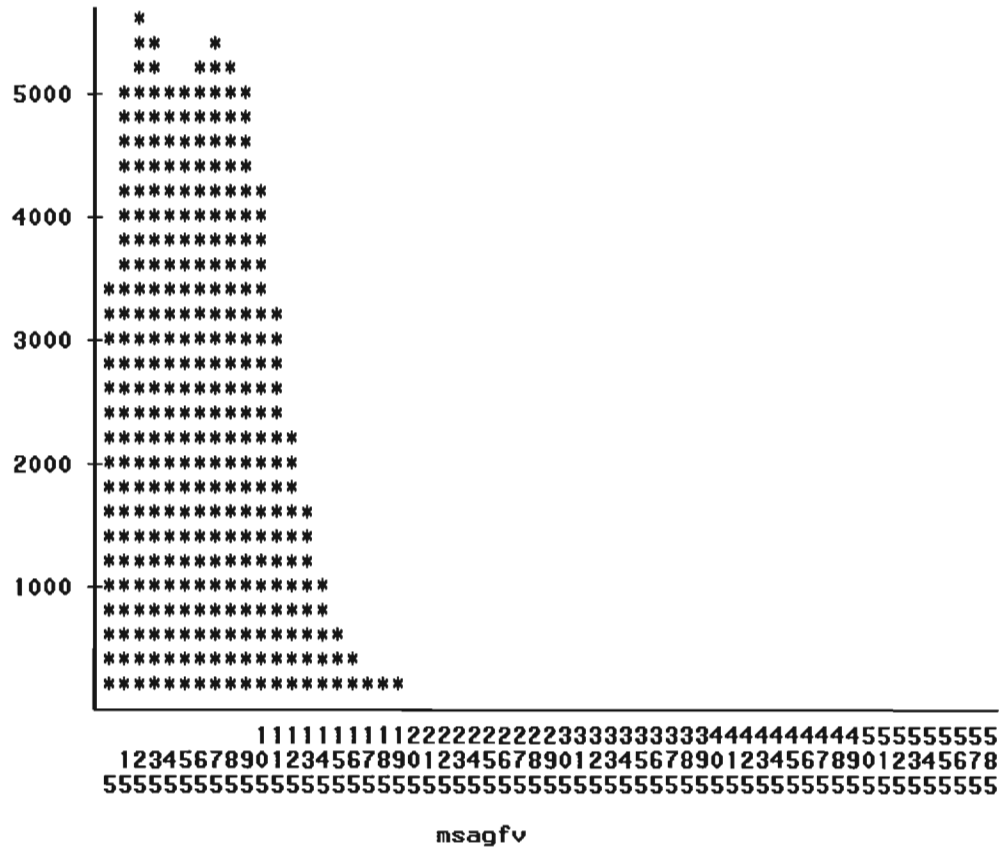


Variable Full Name: Percent Time of Maximum Left Lateral Trunk Angle (%)
 Abbreviated Name: ptmllatp

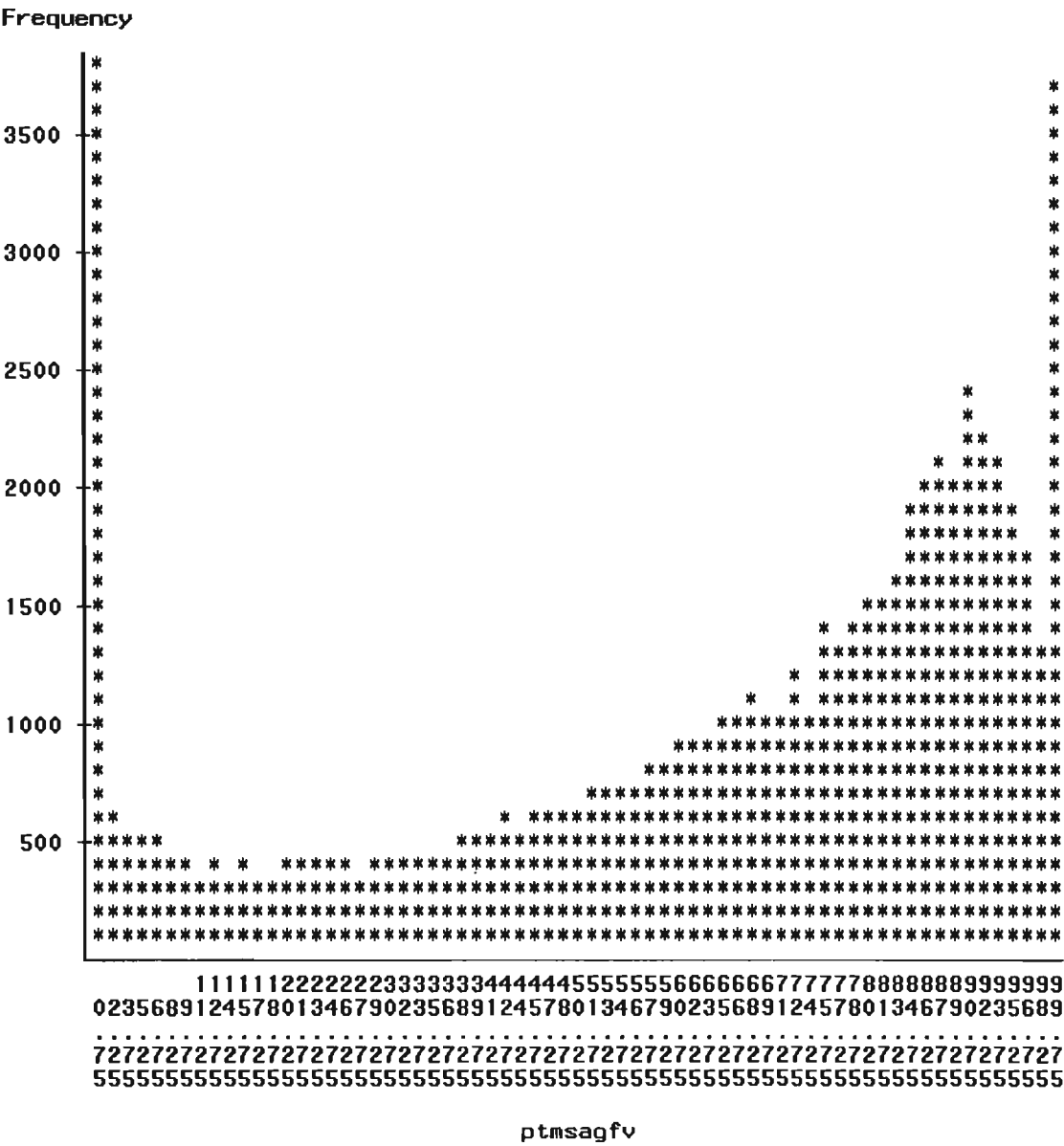


Variable Full Name: Maximum Flexion Sagittal Trunk Velocity (Degrees/s)
Abbreviated Name: msagfv

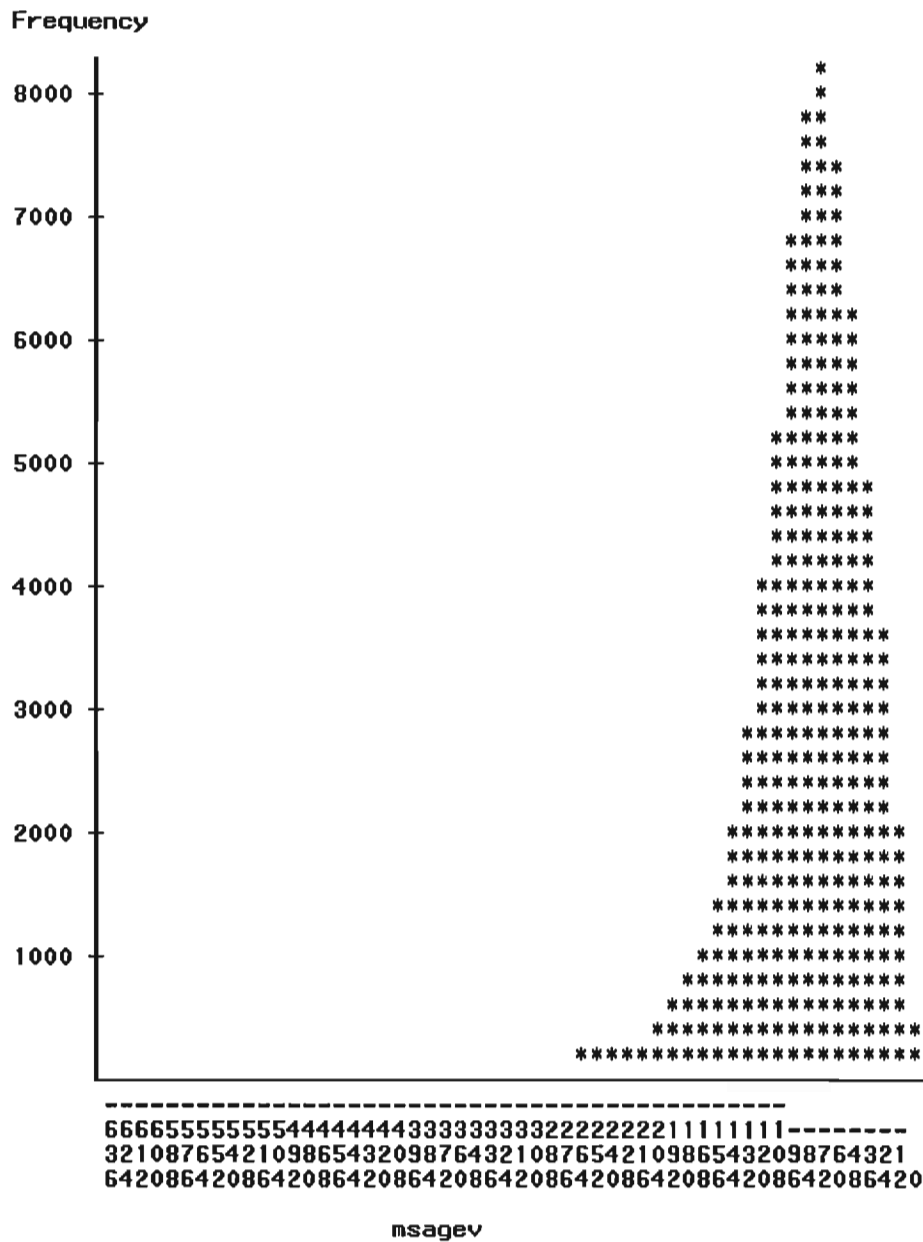
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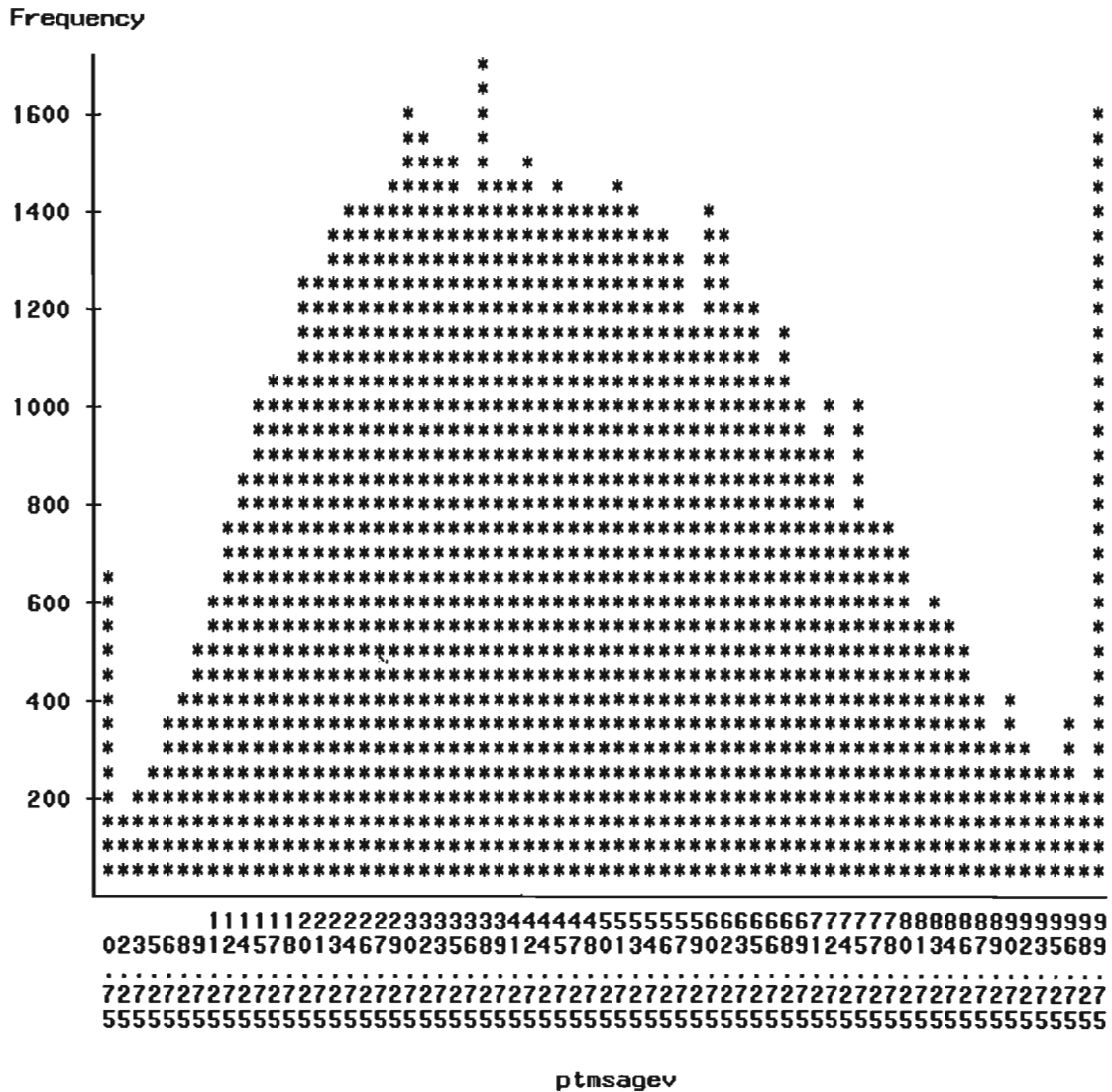
Variable Full Name: Percent Time of Maximum Flexion Sagittal Trunk Velocity (%)
Abbreviated Name: ptmsagfv



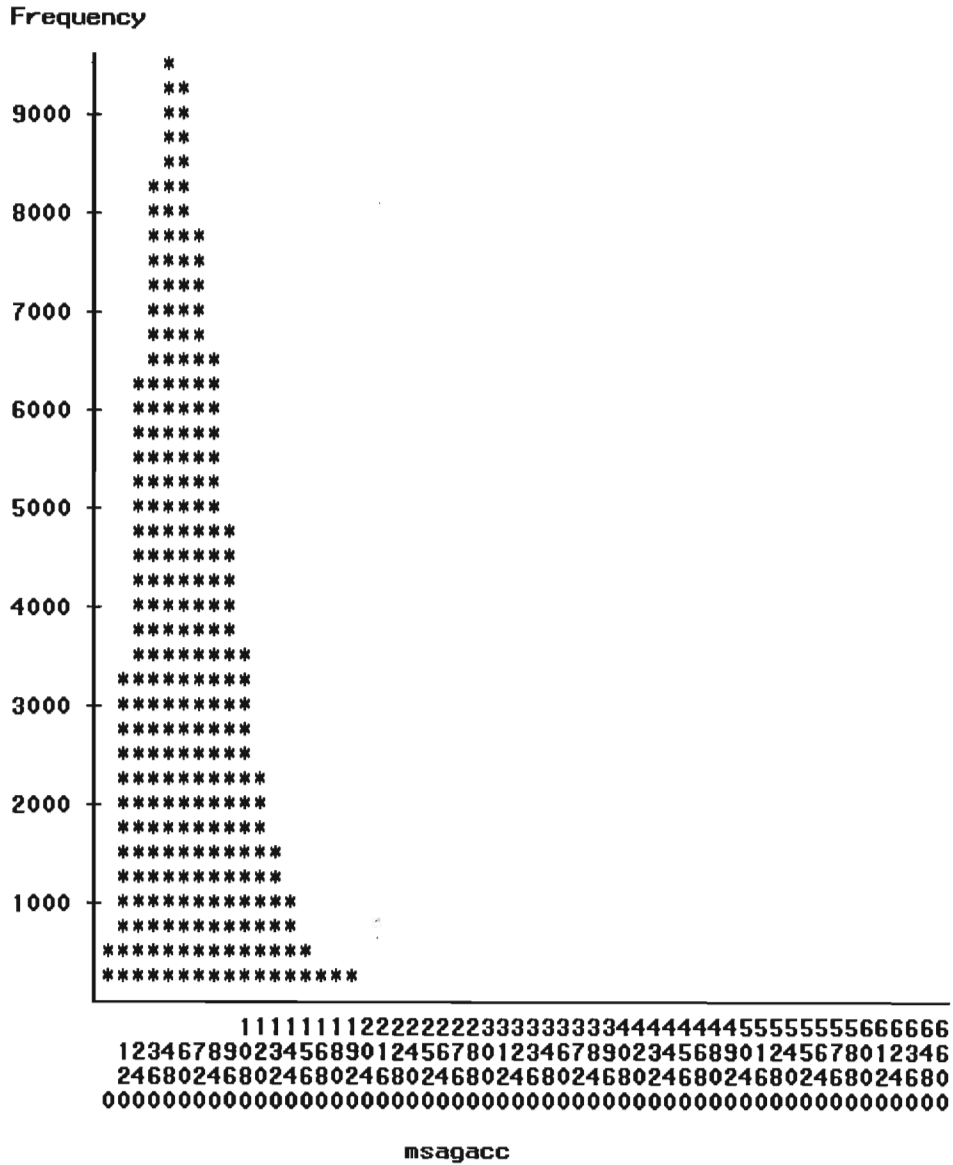
Variable Full Name: Maximum Extension Sagittal Trunk Velocity (Degrees/s)
Abbreviated Name: msagev



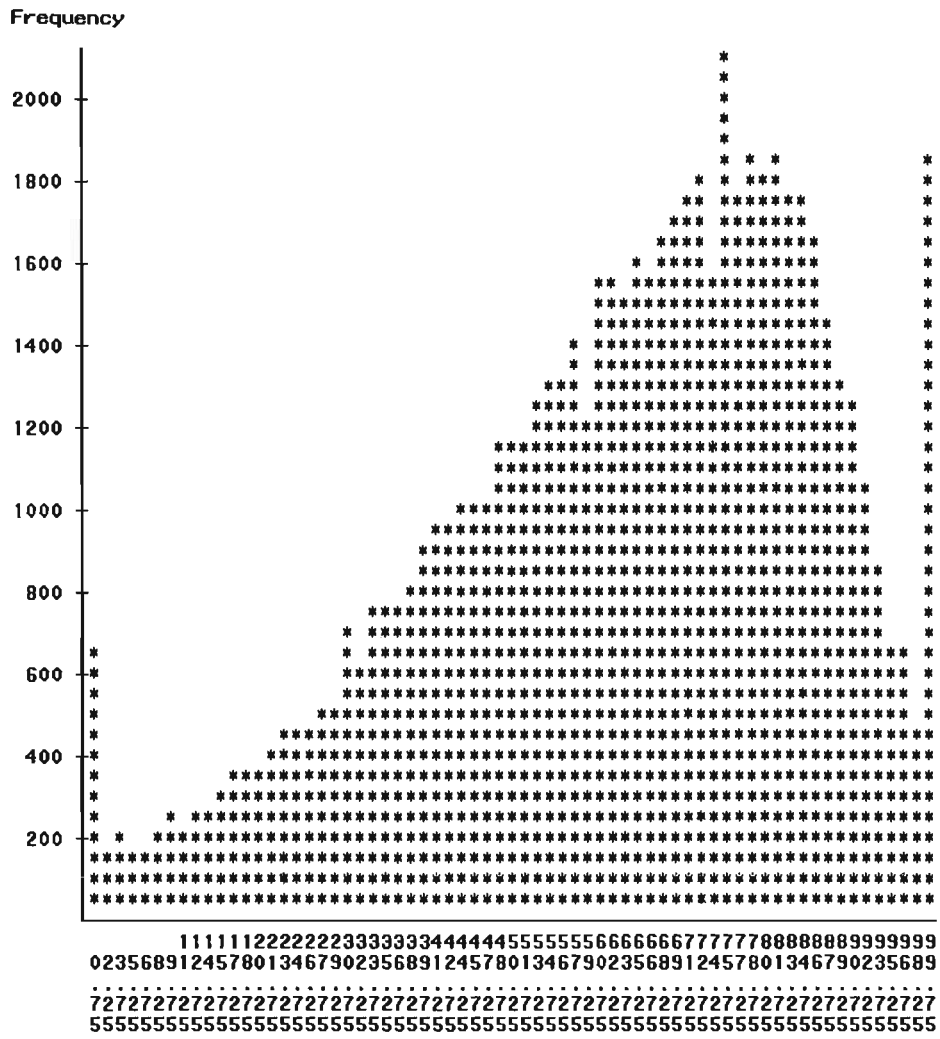
Variable Full Name: Percent Time of Maximum Extension Sagittal Trunk Velocity (%)
Abbreviated Name: ptmsagev



Variable Full Name: Maximum Sagittal Trunk Acceleration (Degrees/s^2)
Abbreviated Name: msagacc

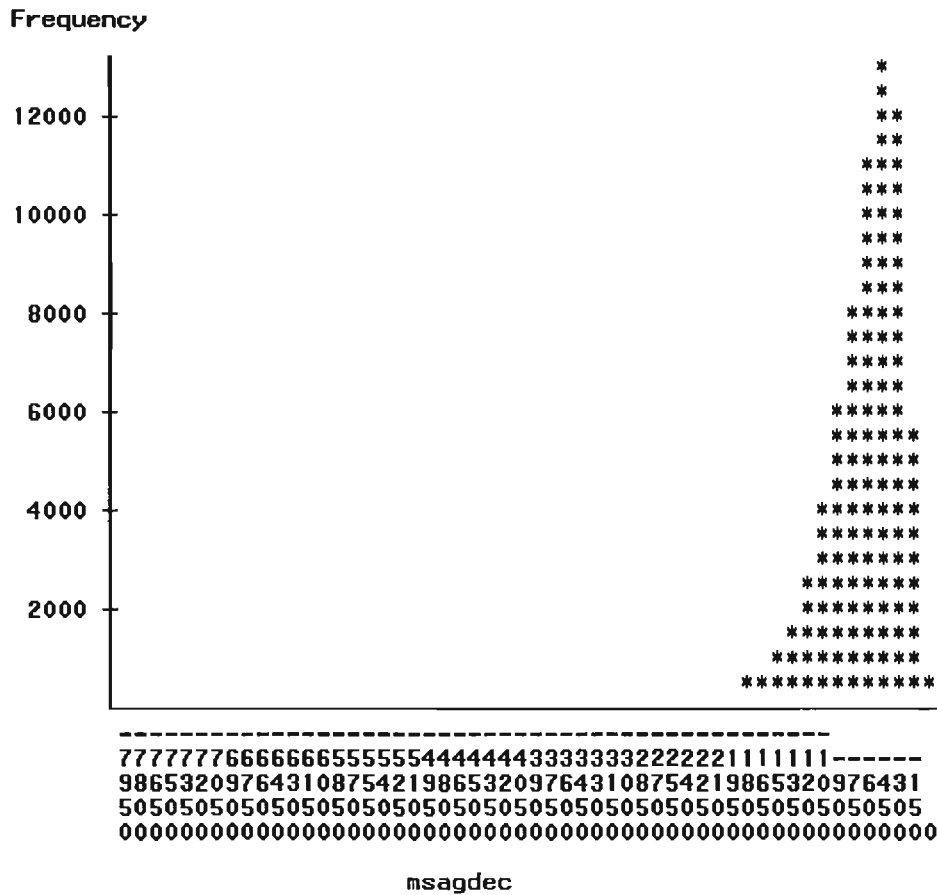


Variable Full Name: Percent Time of Maximum Sagittal Trunk Acceleration (%)
Abbreviated Name: ptmsagacc

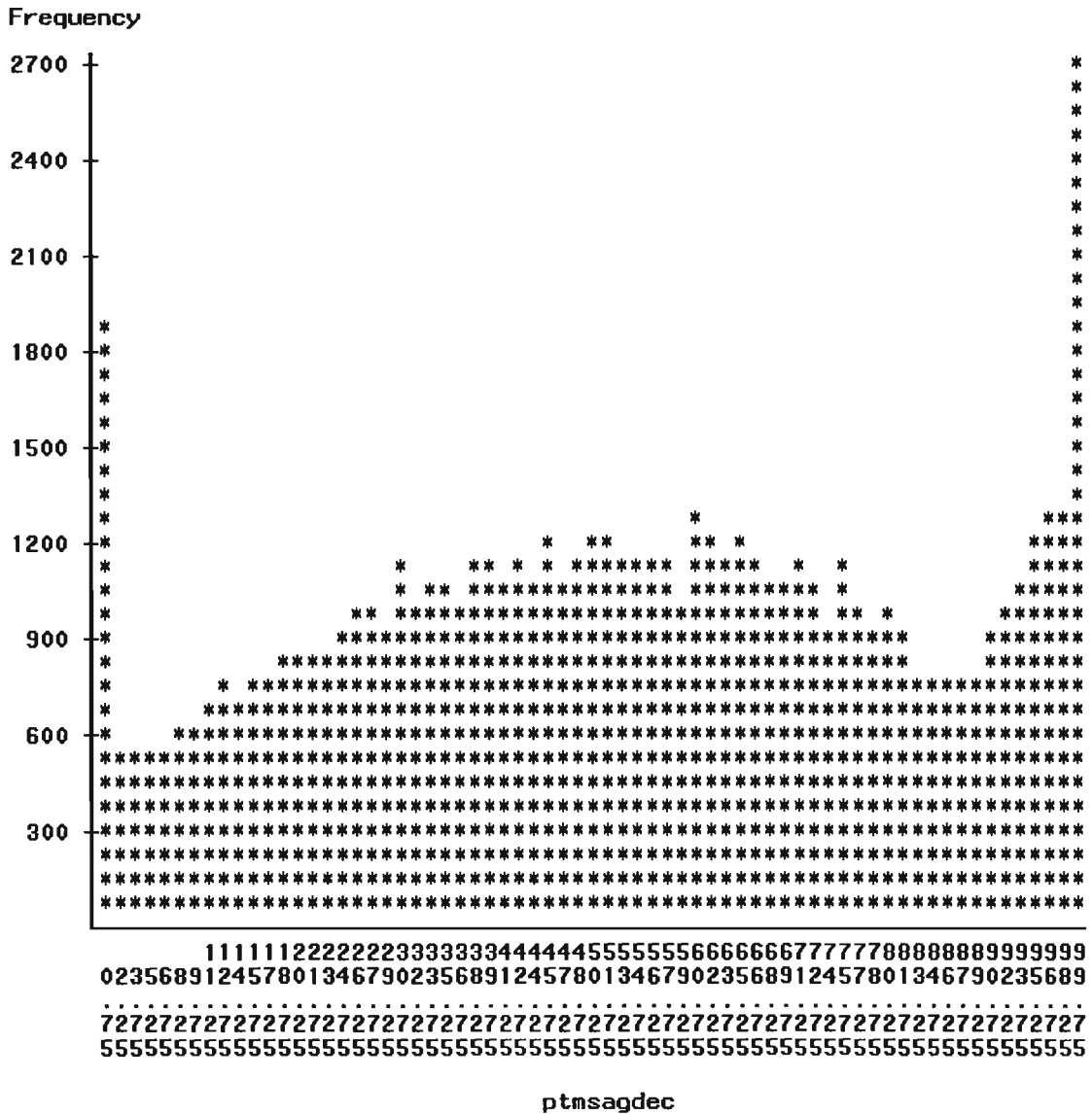


ptmsagacc

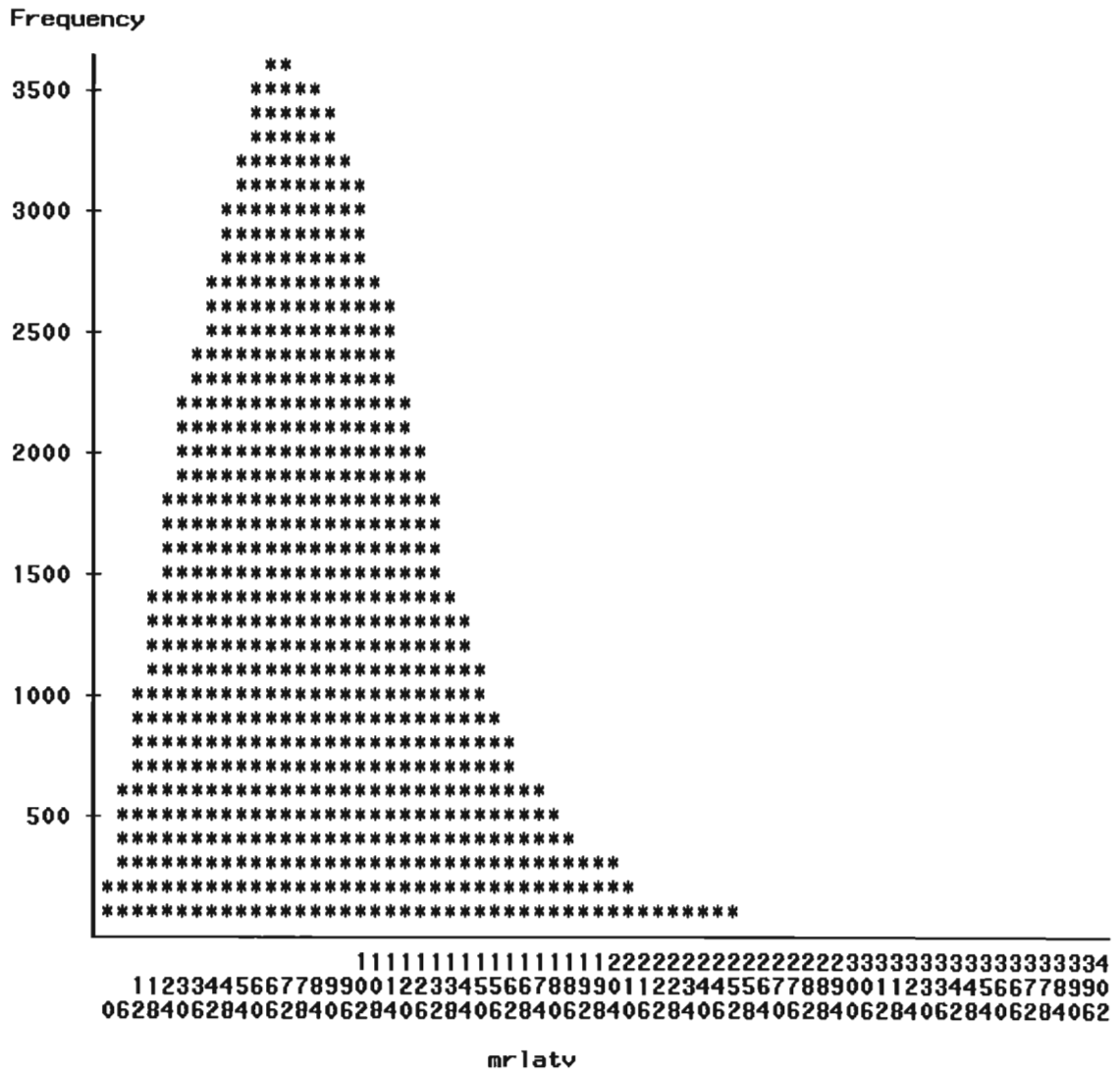
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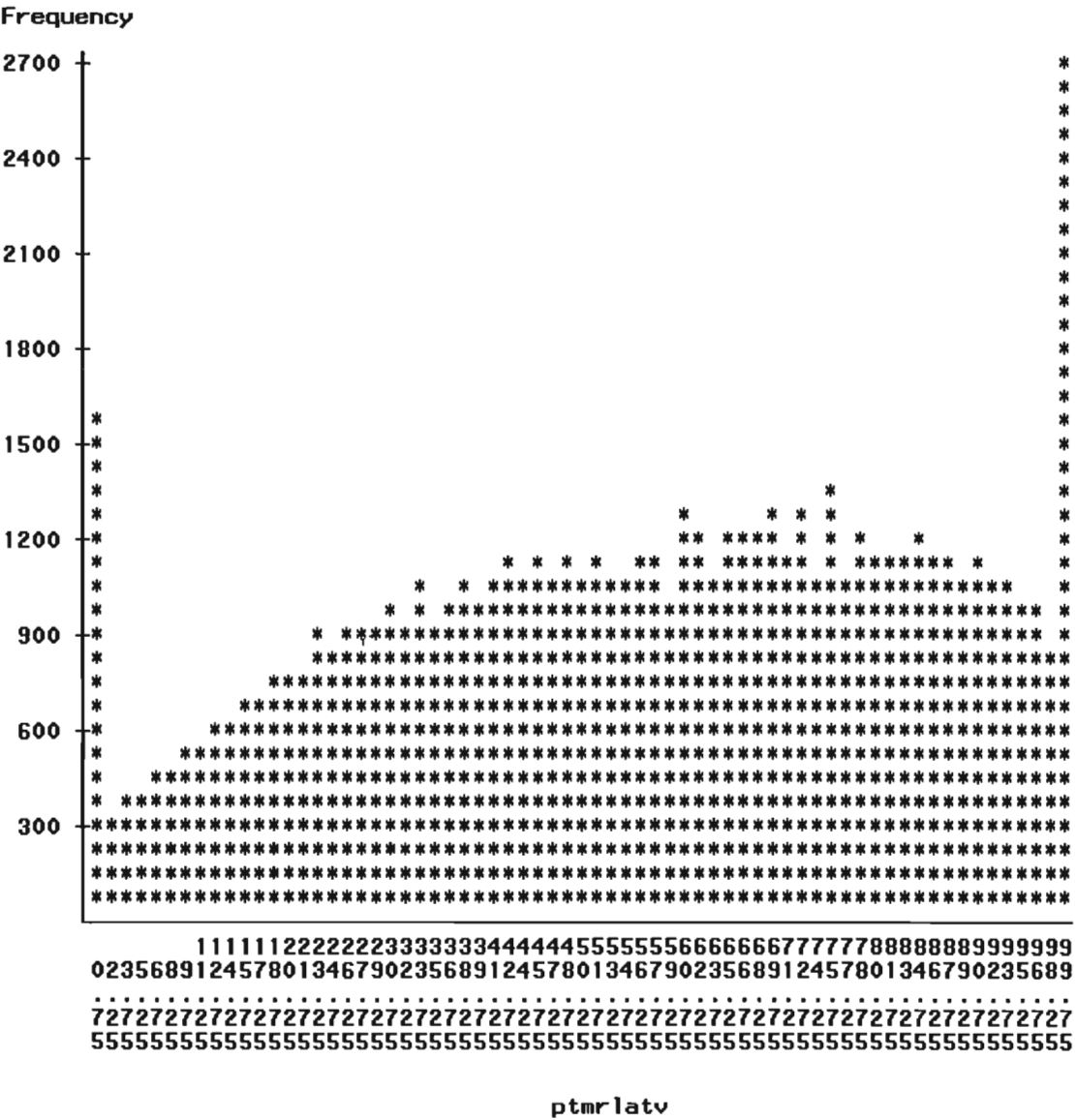
Abbreviated Name: ptmsagdec



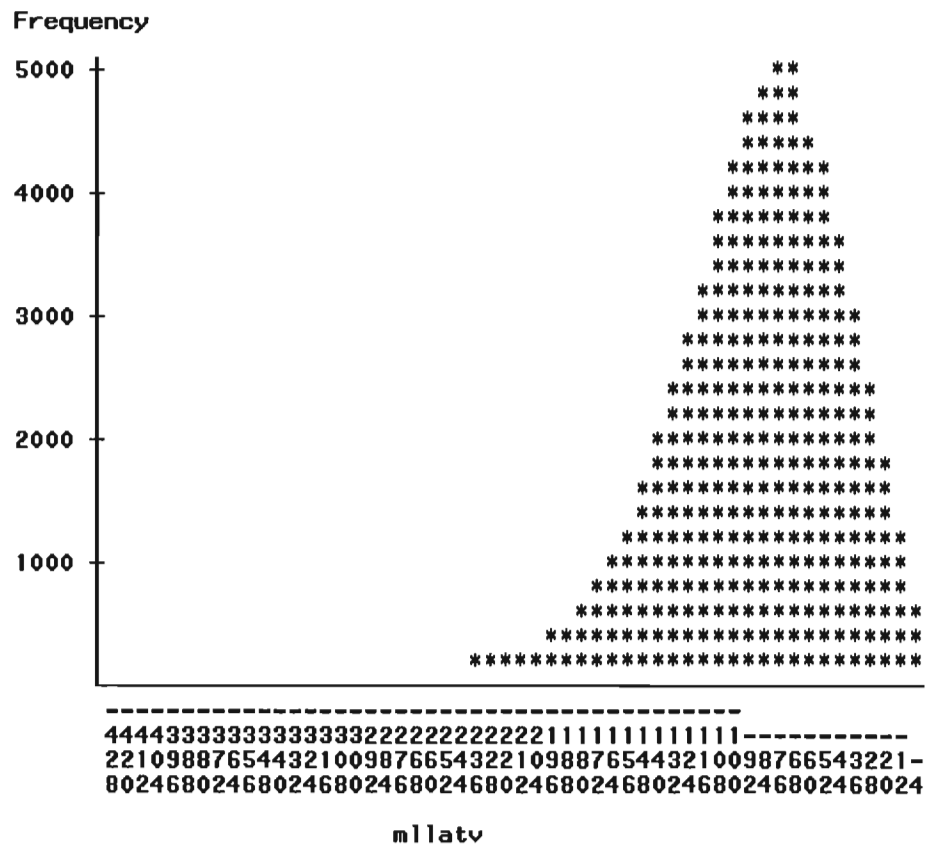
Abbreviated Name: mrlatv



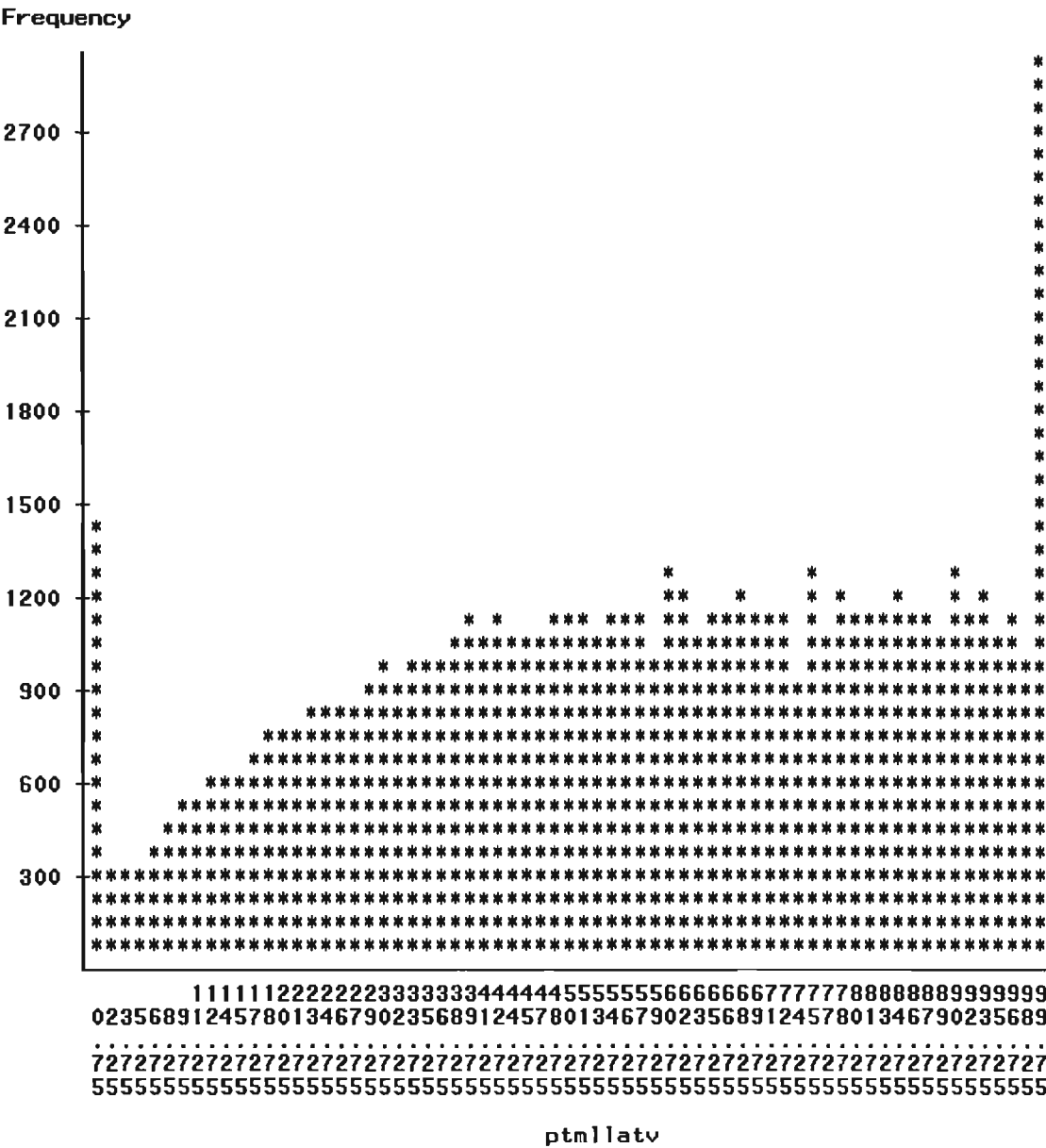
Variable Full Name: Percent Time of Maximum Rightwards Lateral Trunk Velocity (%)
Abbreviated Name: ptmrlatv



Variable Full Name: Maximum Leftwards Lateral Trunk Velocity (Degrees/s)
Abbreviated Name: mllatv



Variable Full Name: Percent Time of Maximum Leftwards Lateral Trunk Velocity (%)
Abbreviated Name: ptmllatv

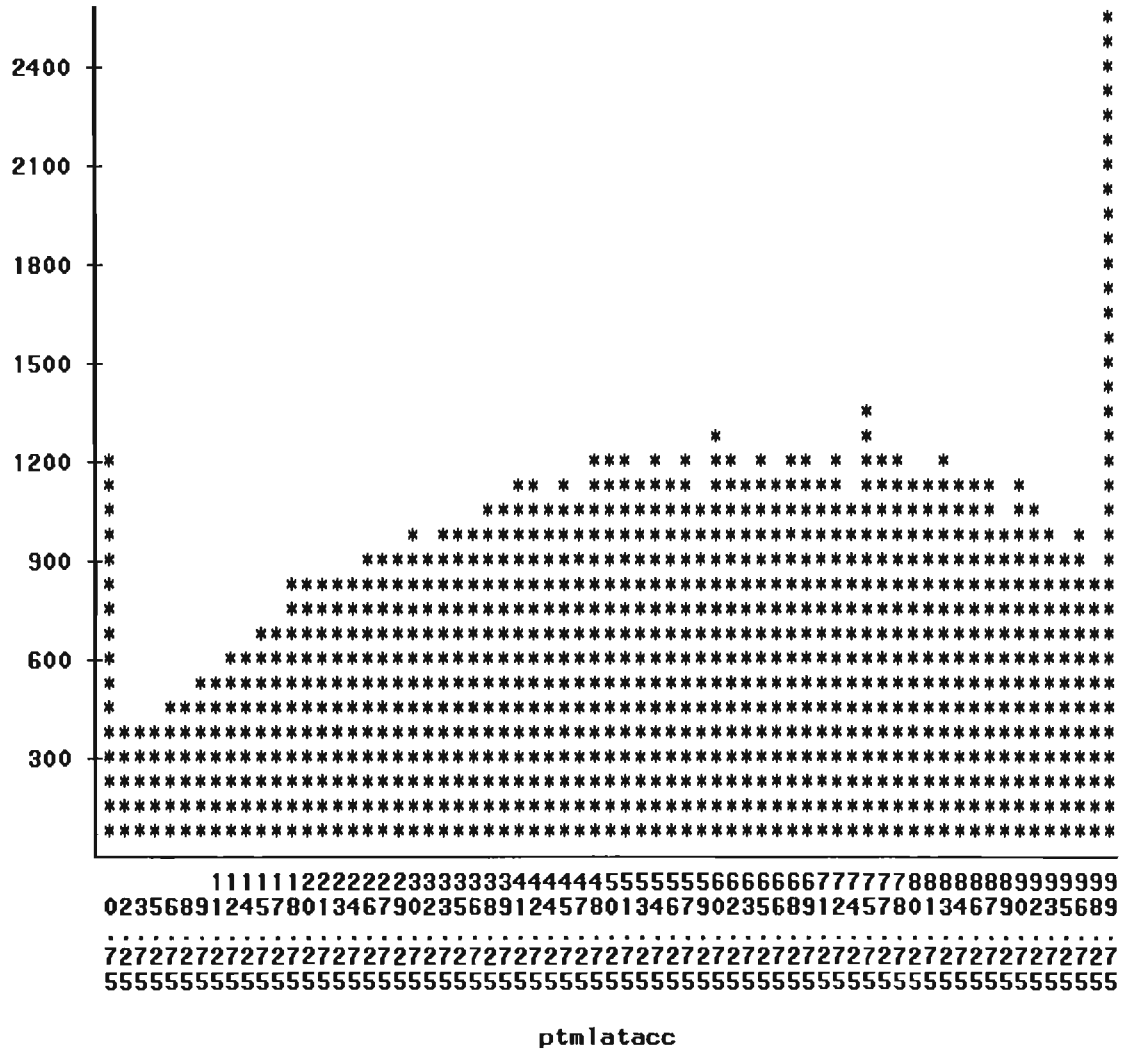


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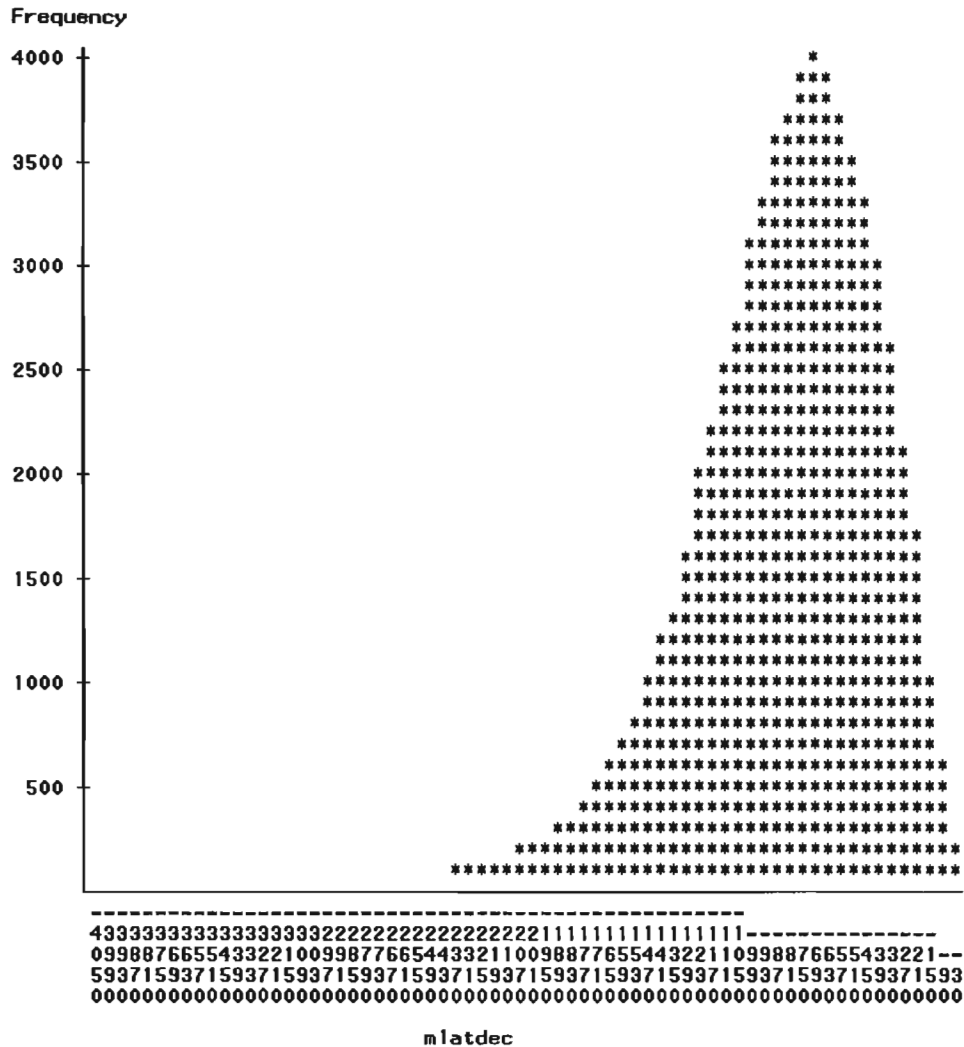


Variable Full Name: Percent Time of Maximum Lateral Trunk Acceleration (%)
Abbreviated Name: ptmlatacc

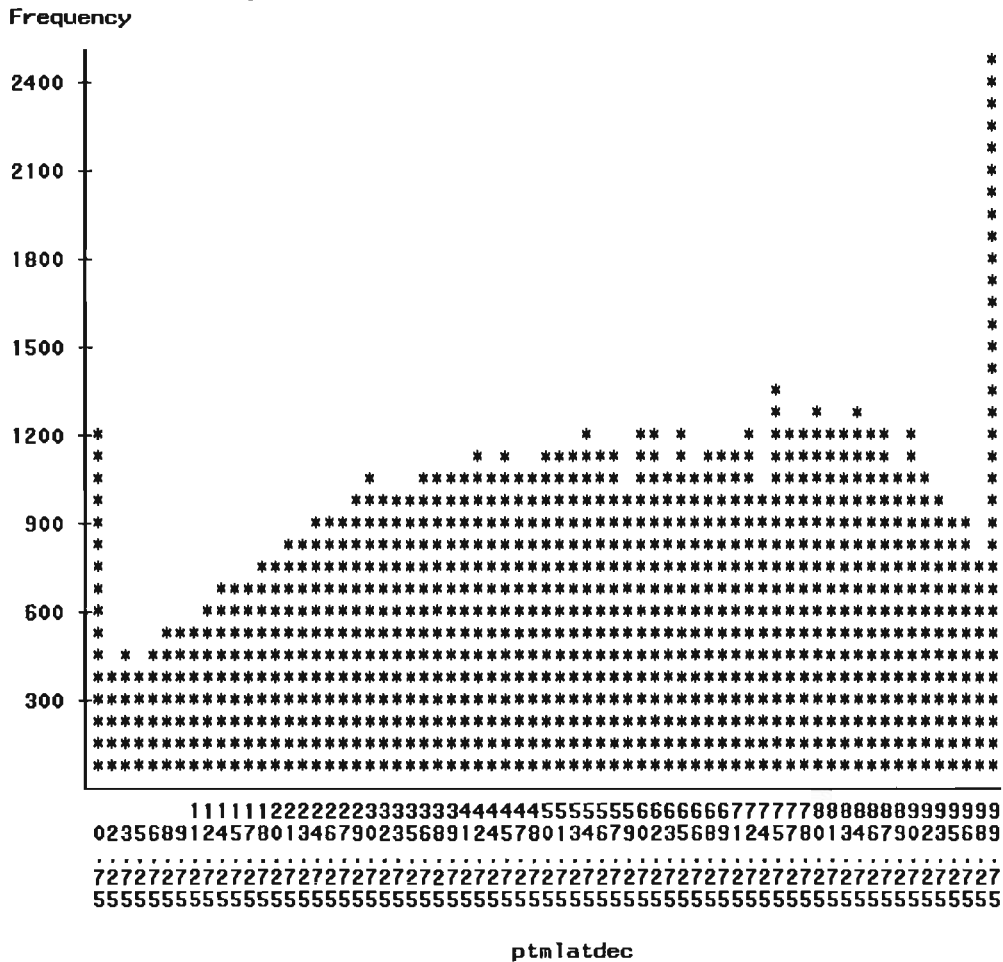
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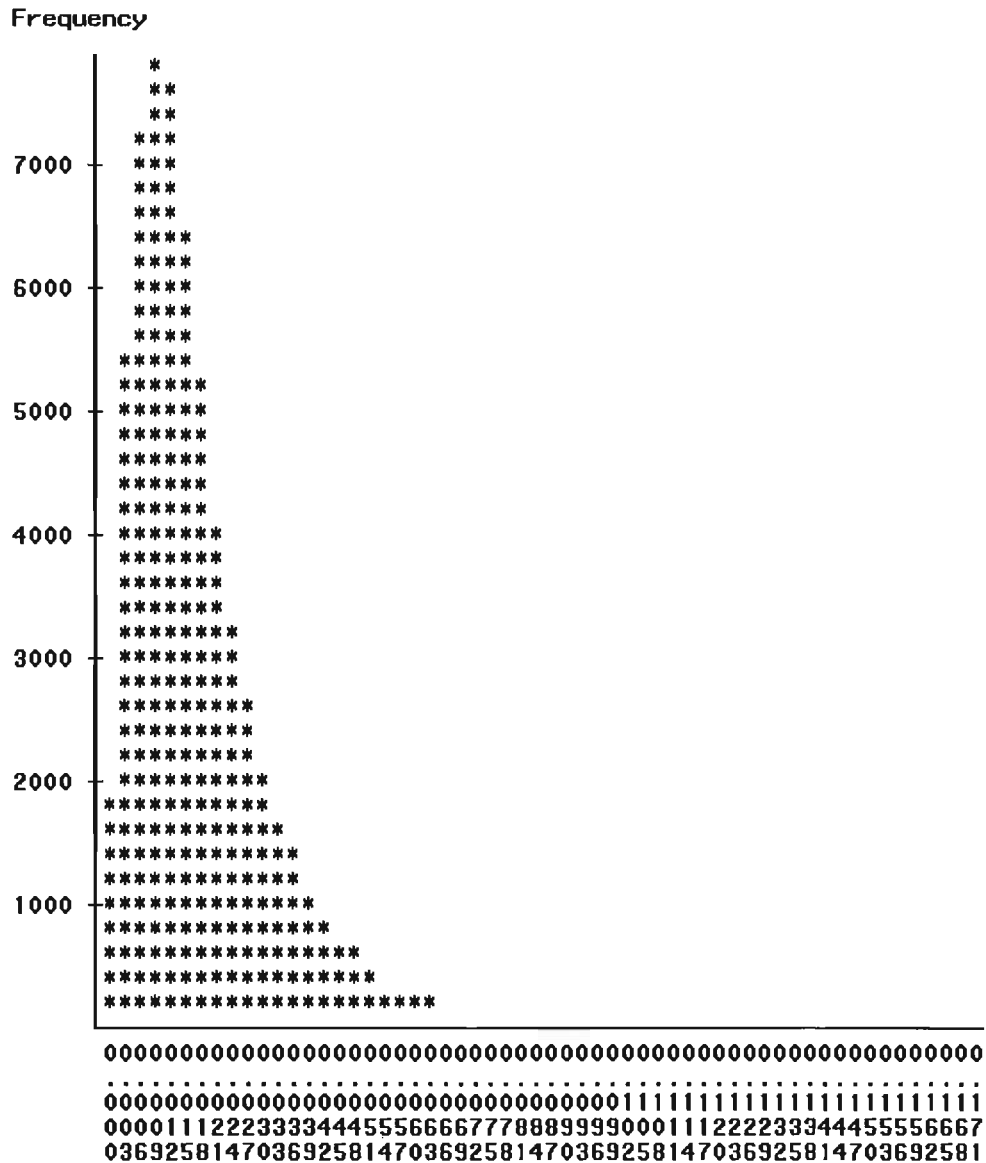
Abbreviated Name: mlatdec



Abbreviated Name: ptmlatdec

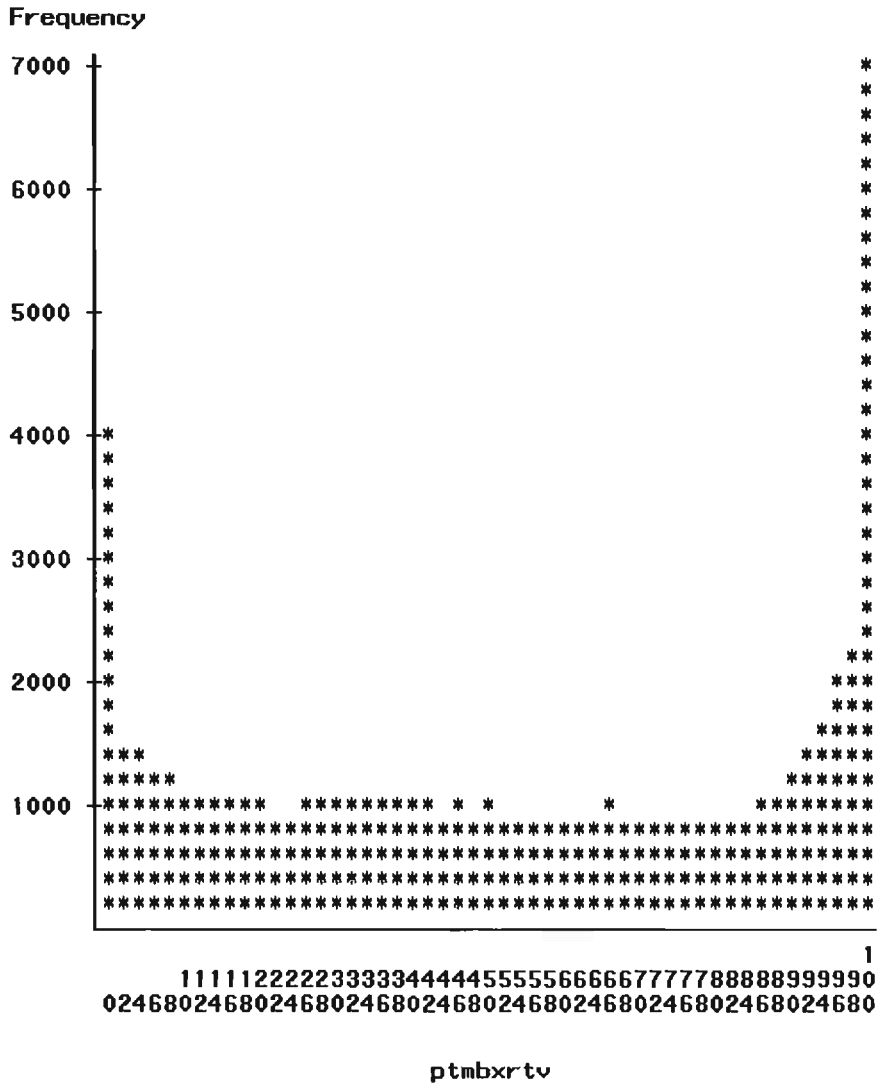


Abbreviated Name: mbxrtvel



mbxr tve l

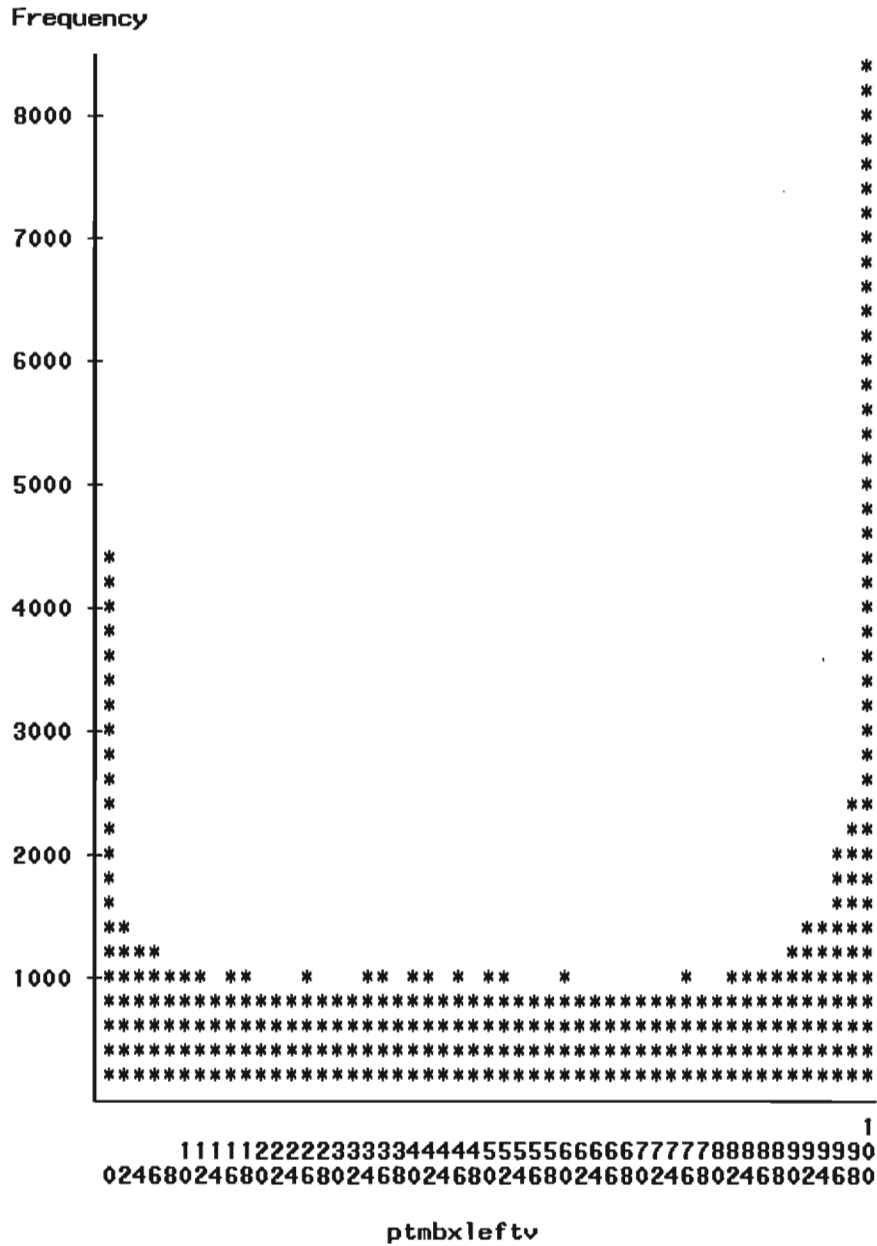
Variable Full Name: Percent Time of Maximum Box Rightwards X Velocity (%)
Abbreviated Name: ptmbxrtv



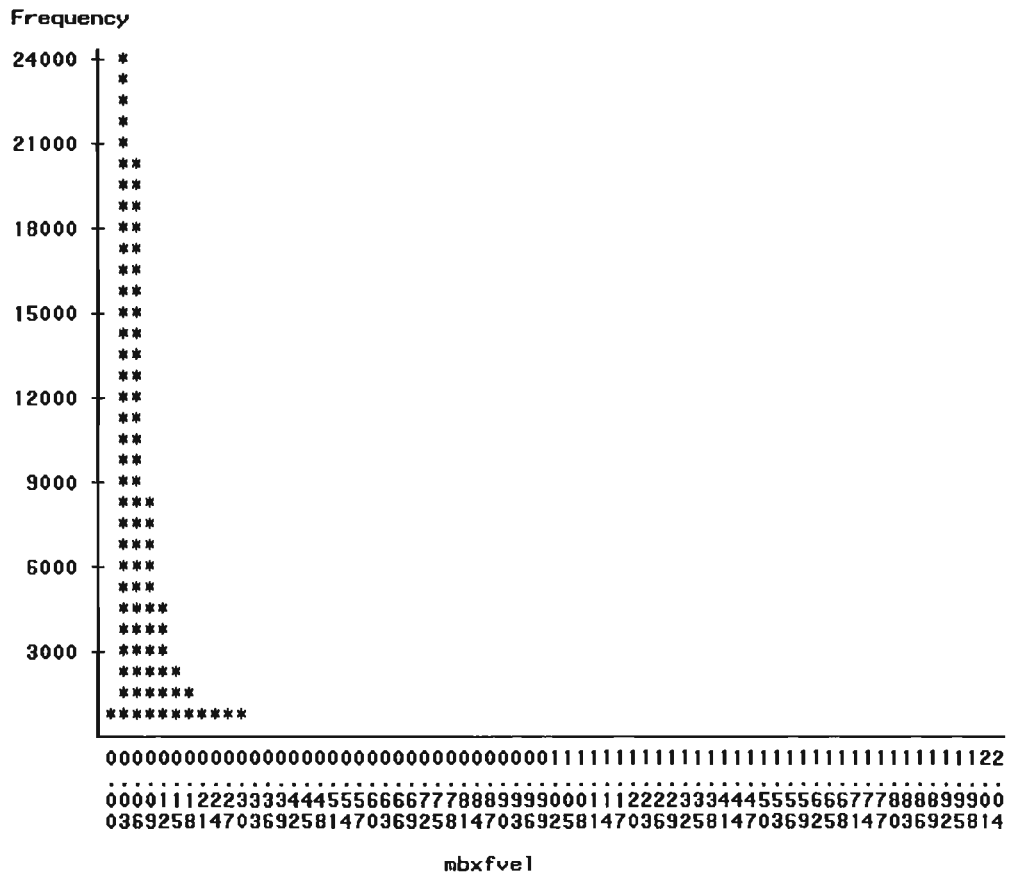
Abbreviated Name: mbxleftv



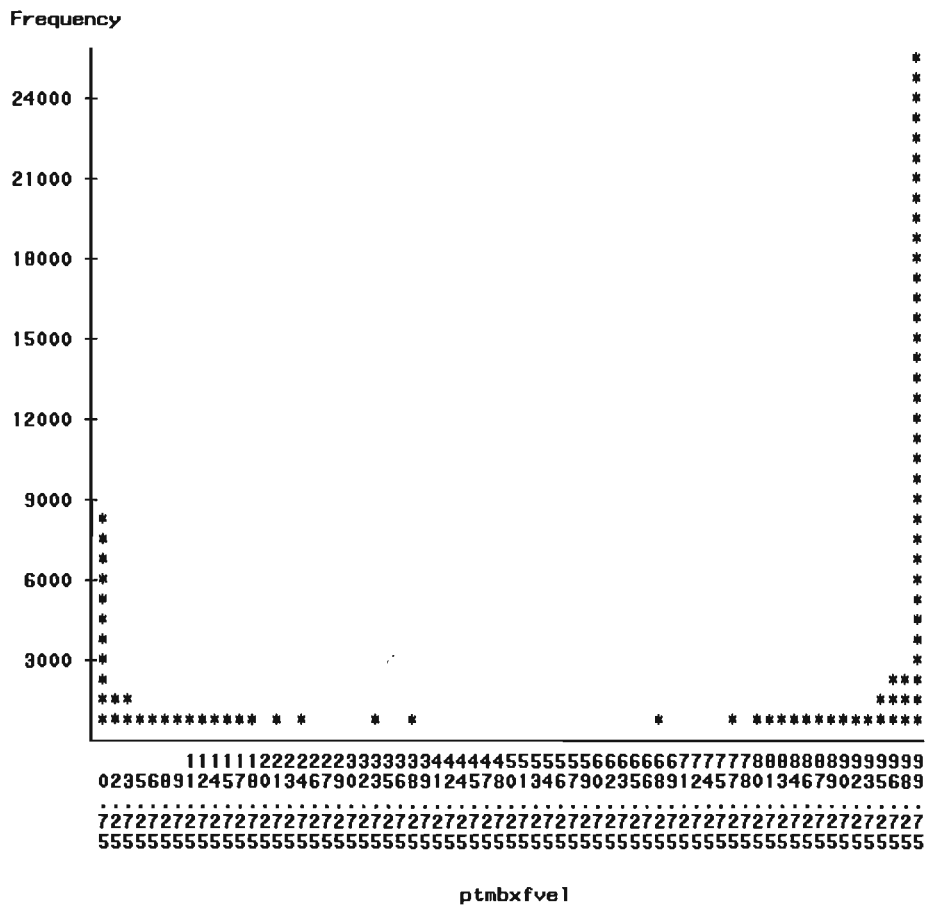
Variable Full Name: Percent Time of Maximum Box Leftwards X Velocity (%)
Abbreviated Name: ptmbxleftv



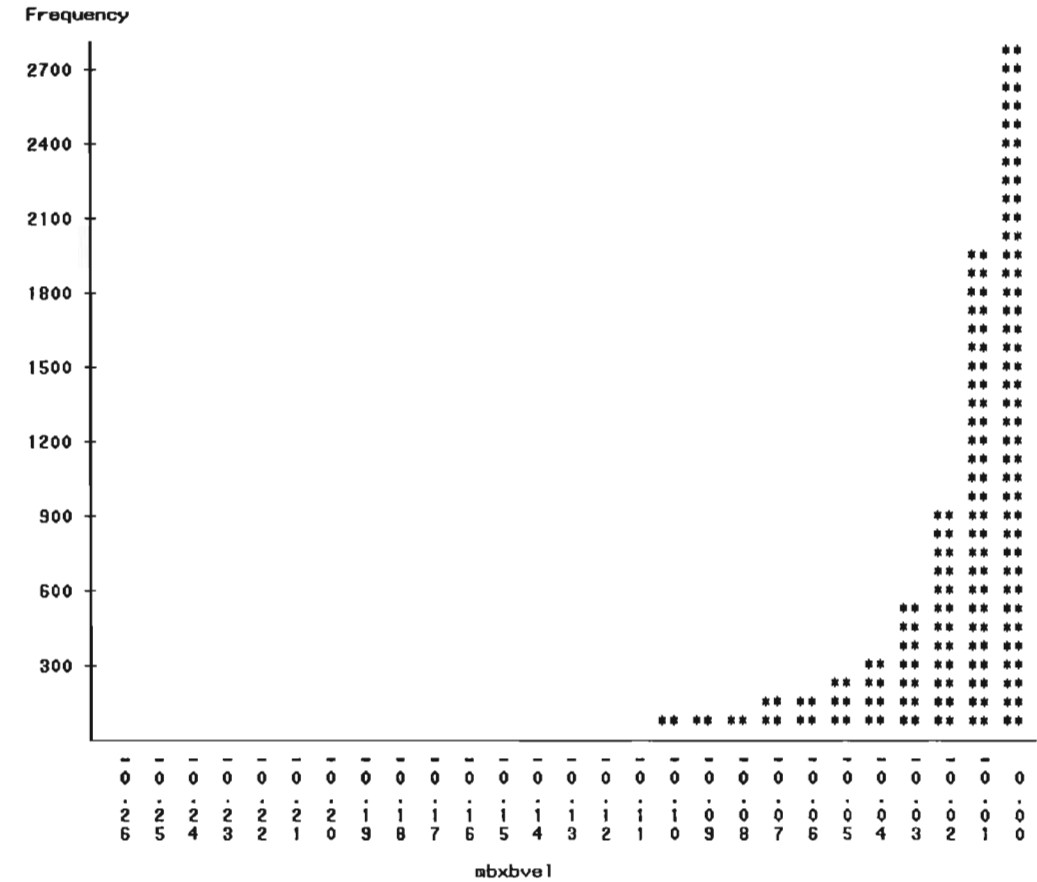
Abbreviated Name: mbxfvel



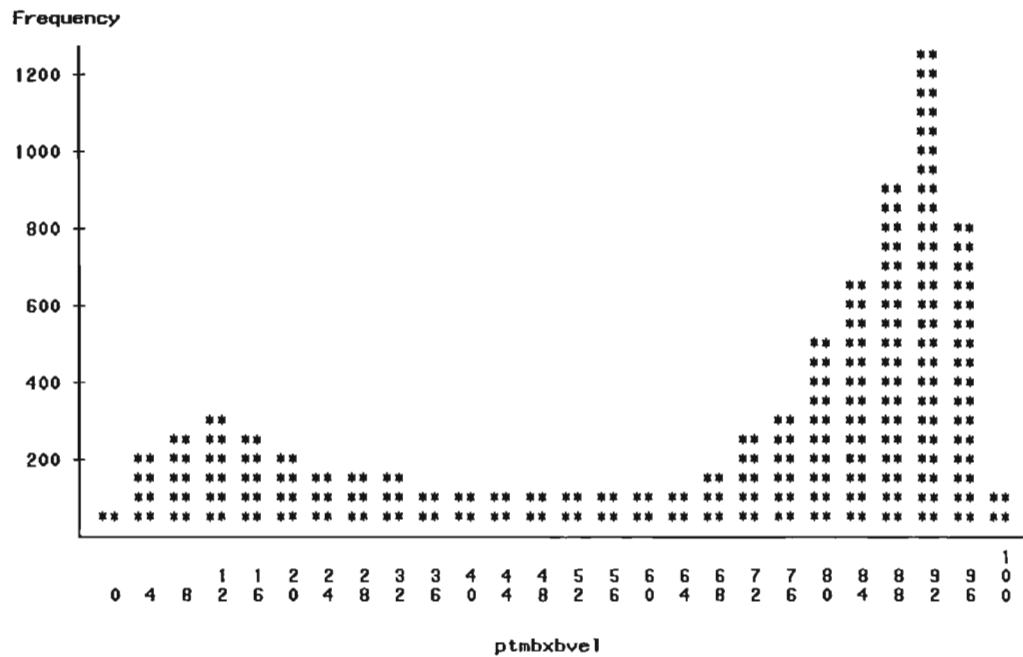
Variable Full Name: Percent Time of Maximum Box Forwards Y Velocity (%)
Abbreviated Name: ptmbxfvel



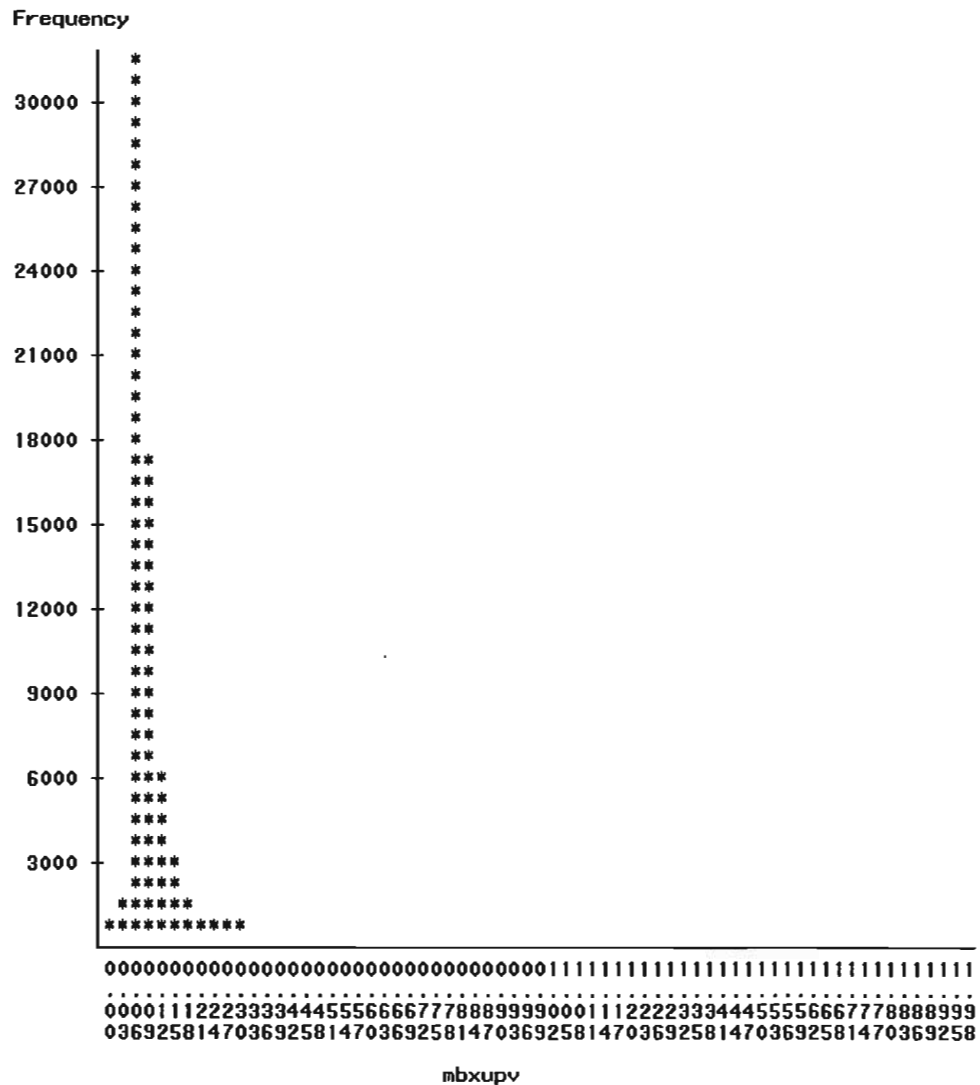
Variable Full Name: Maximum Box Backwards Y Velocity (m/s)
Abbreviated Name: mbxbvel



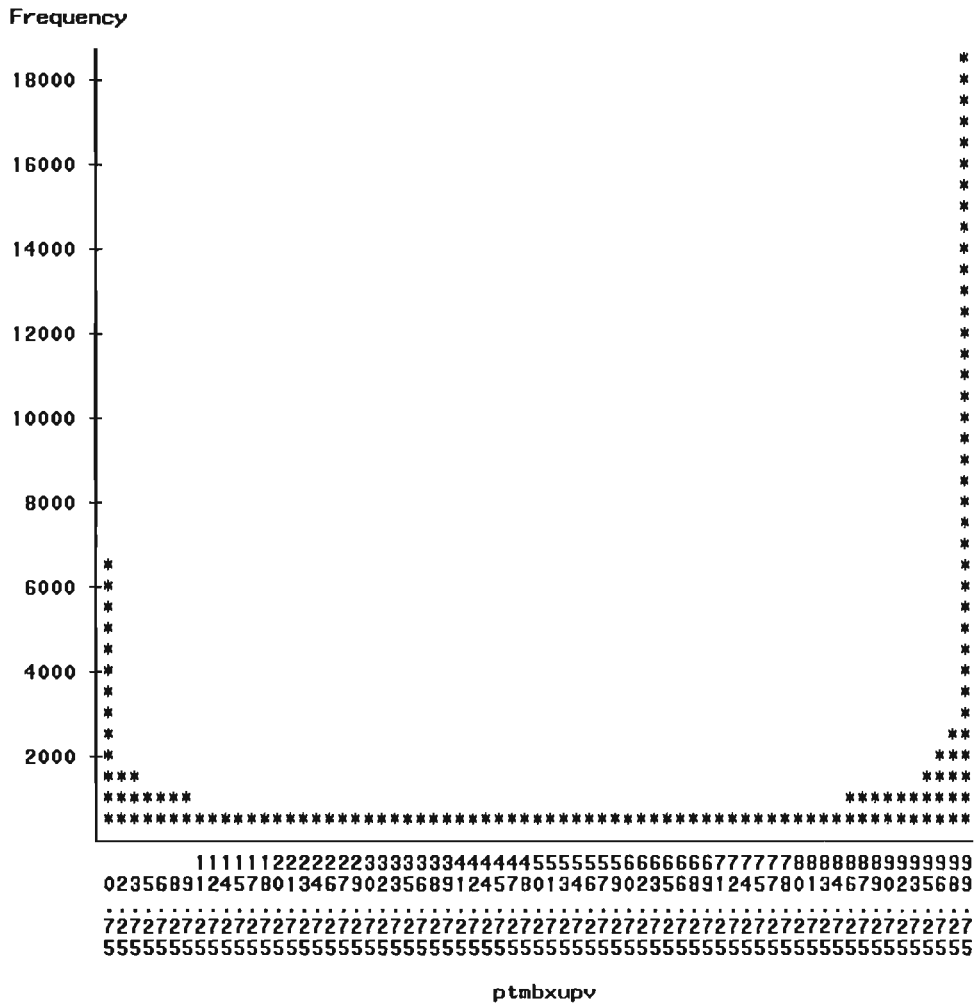
Variable Full Name: Percent Time of Maximum Box Backwards Y Velocity (%)
Abbreviated Name: ptmbxbvel



Variable Full Name: Maximum Box Up Z Velocity (m/s)
Abbreviated Name: mbxupv



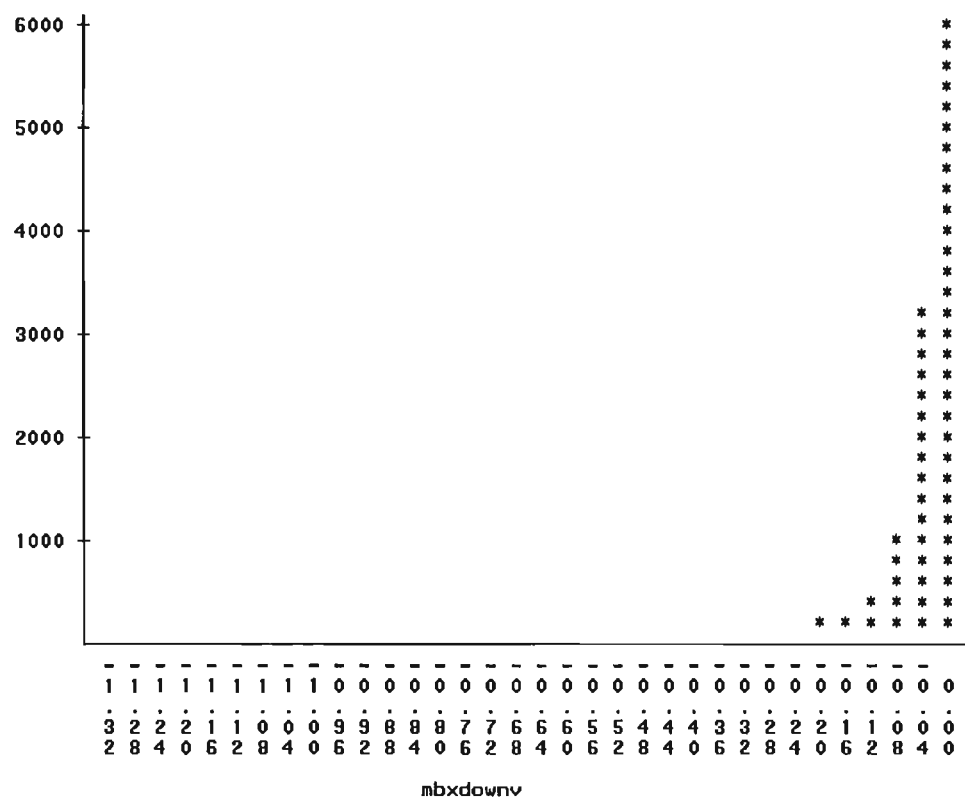
Variable Full Name: Percent Time of Maximum Box Up Z Velocity (%)
Abbreviated Name: ptmbxupv



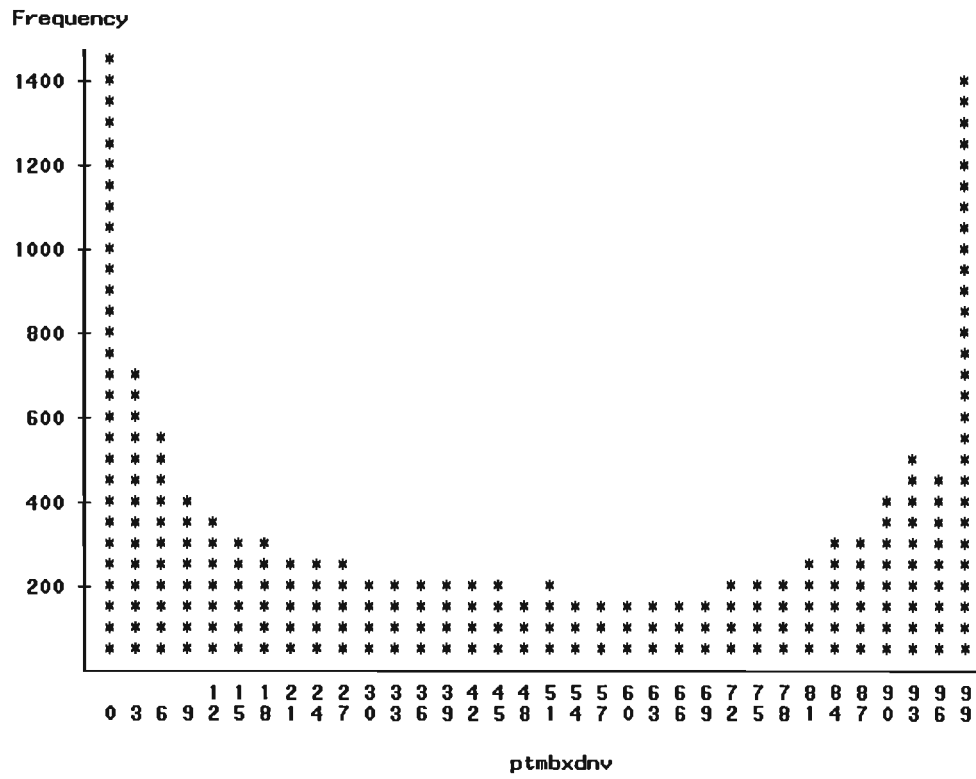
Variable Full Name: Maximum Box Down Z Velocity (m/s)

Abbreviated Name: mbxdownv

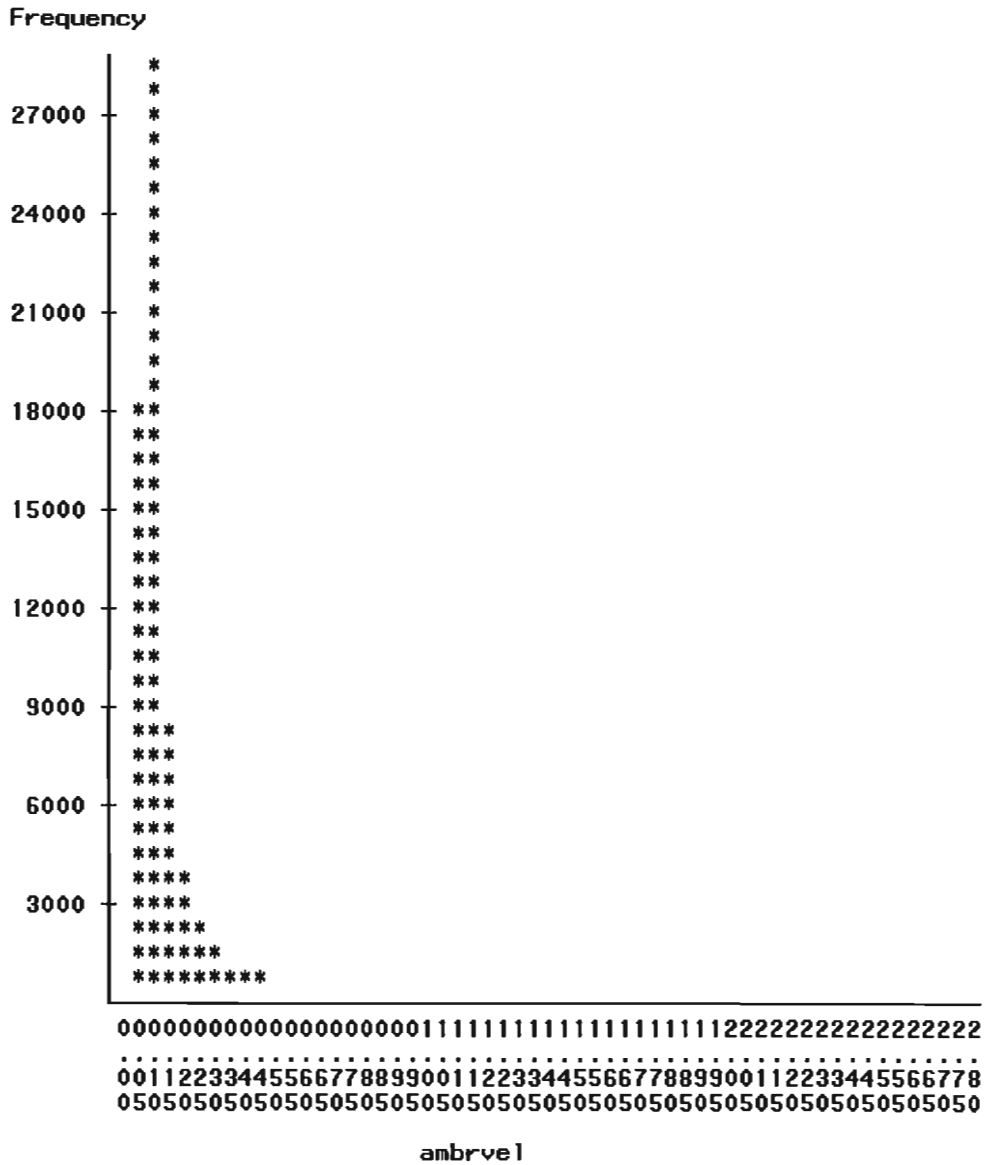
Frequency



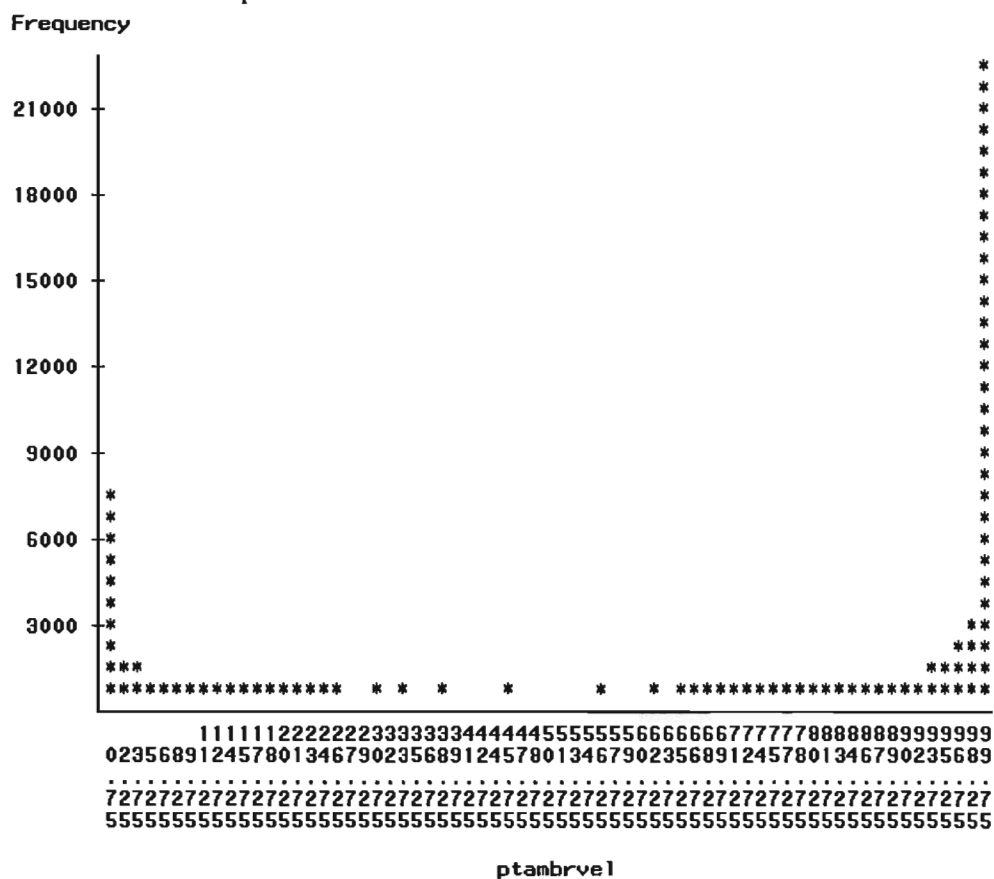
Variable Full Name: Percent Time of Maximum Box Down Z Velocity (%)
 Abbreviated Name: ptmbxdnv



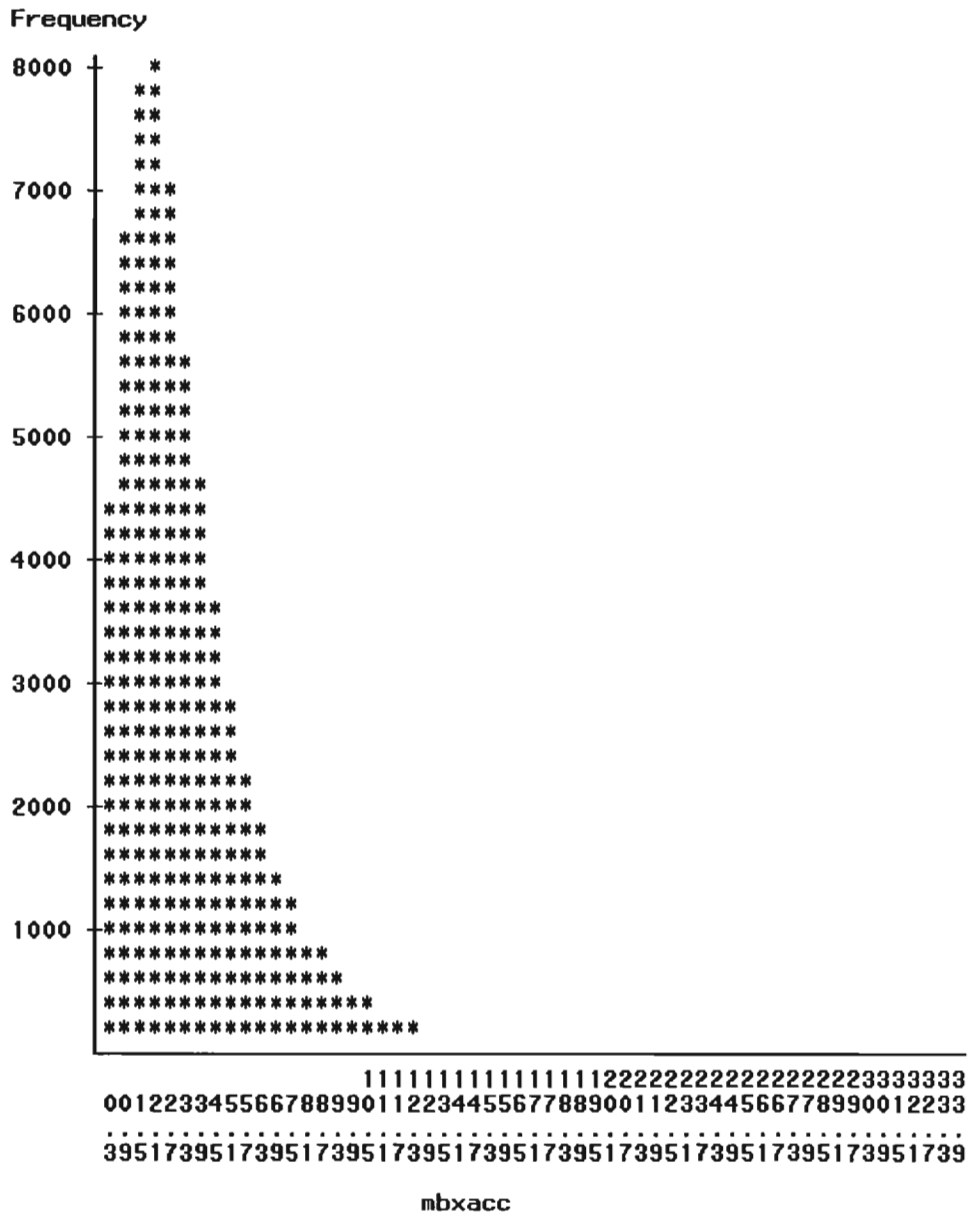
Variable Full Name: Absolute Maximum Box Resultant Velocity (m/s)
Abbreviated Name: ambrvel



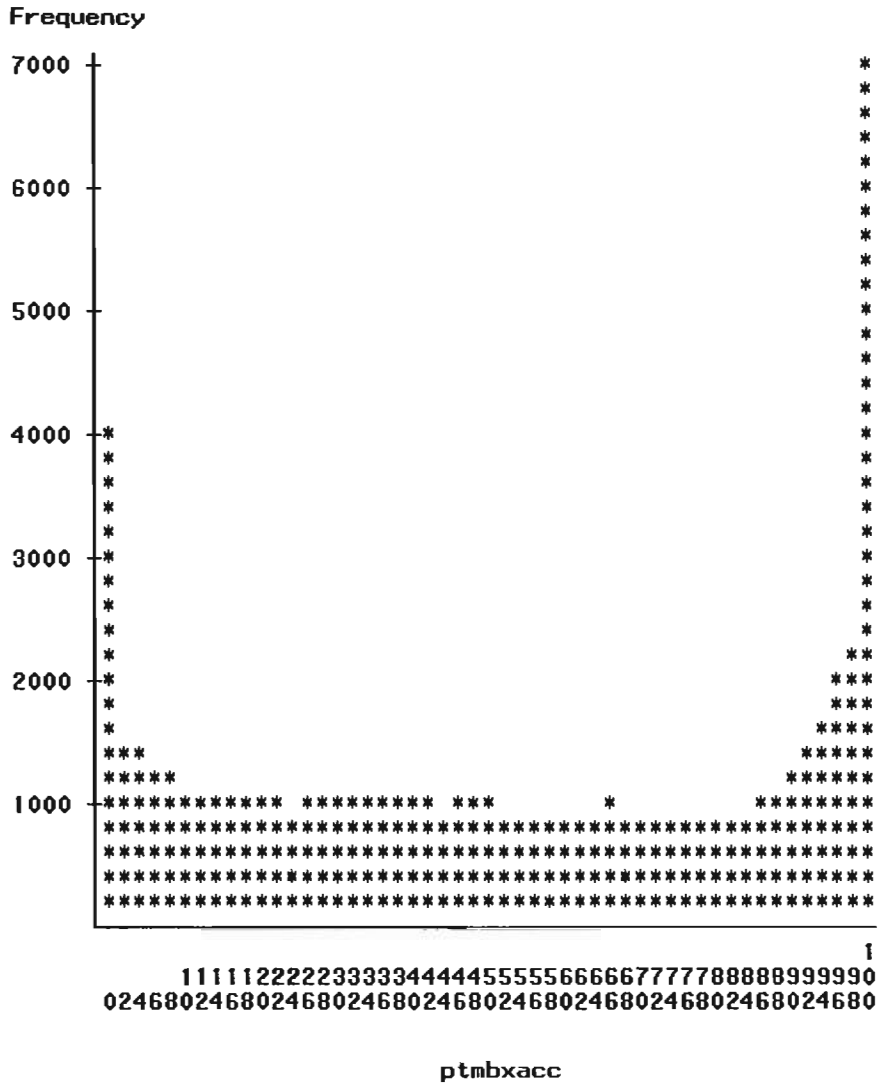
Variable Full Name: Percent Time of Absolute Maximum Box Resultant Velocity (%)
Abbreviated Name: ptambrvel



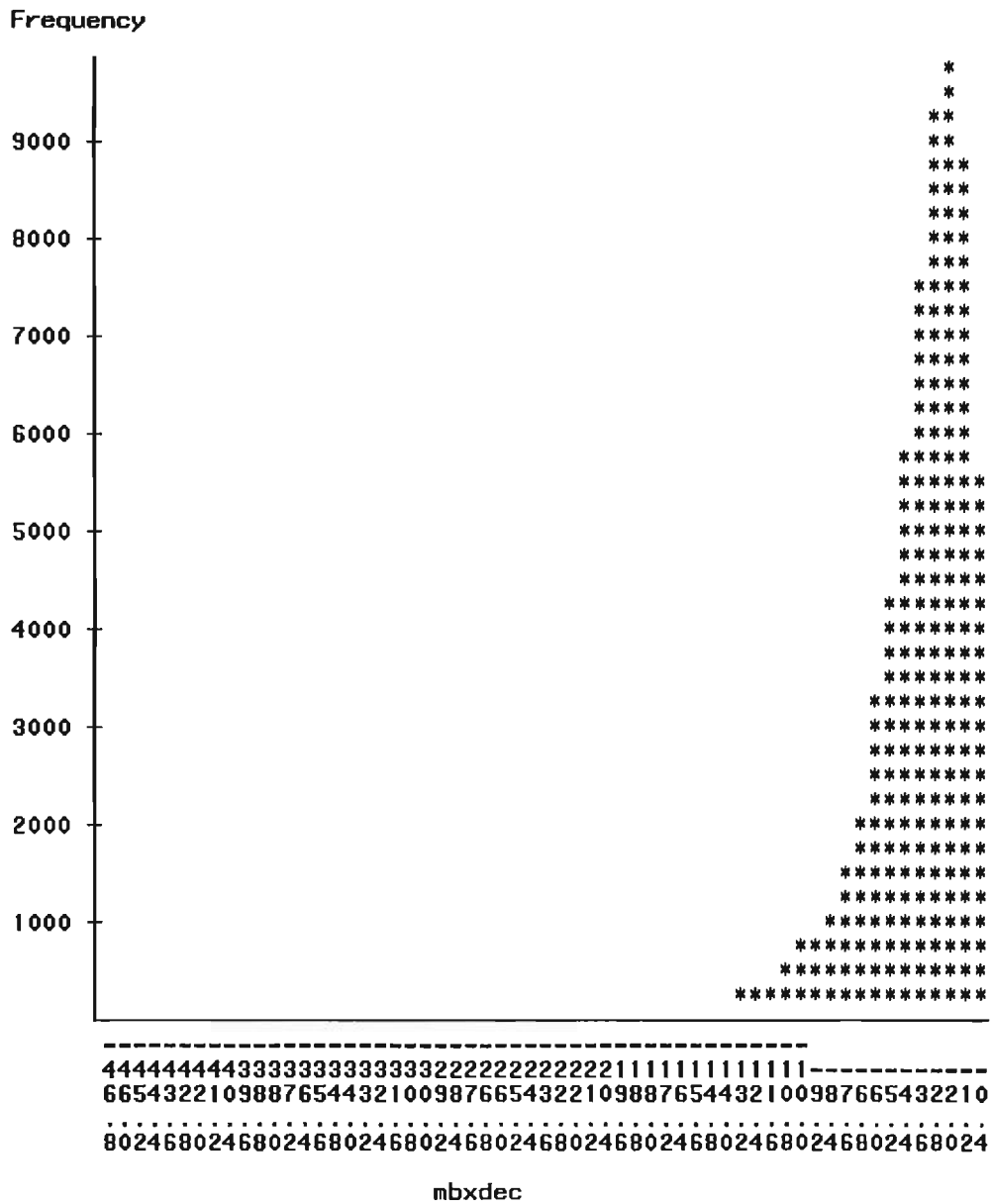
Abbreviated Name: mbxacc



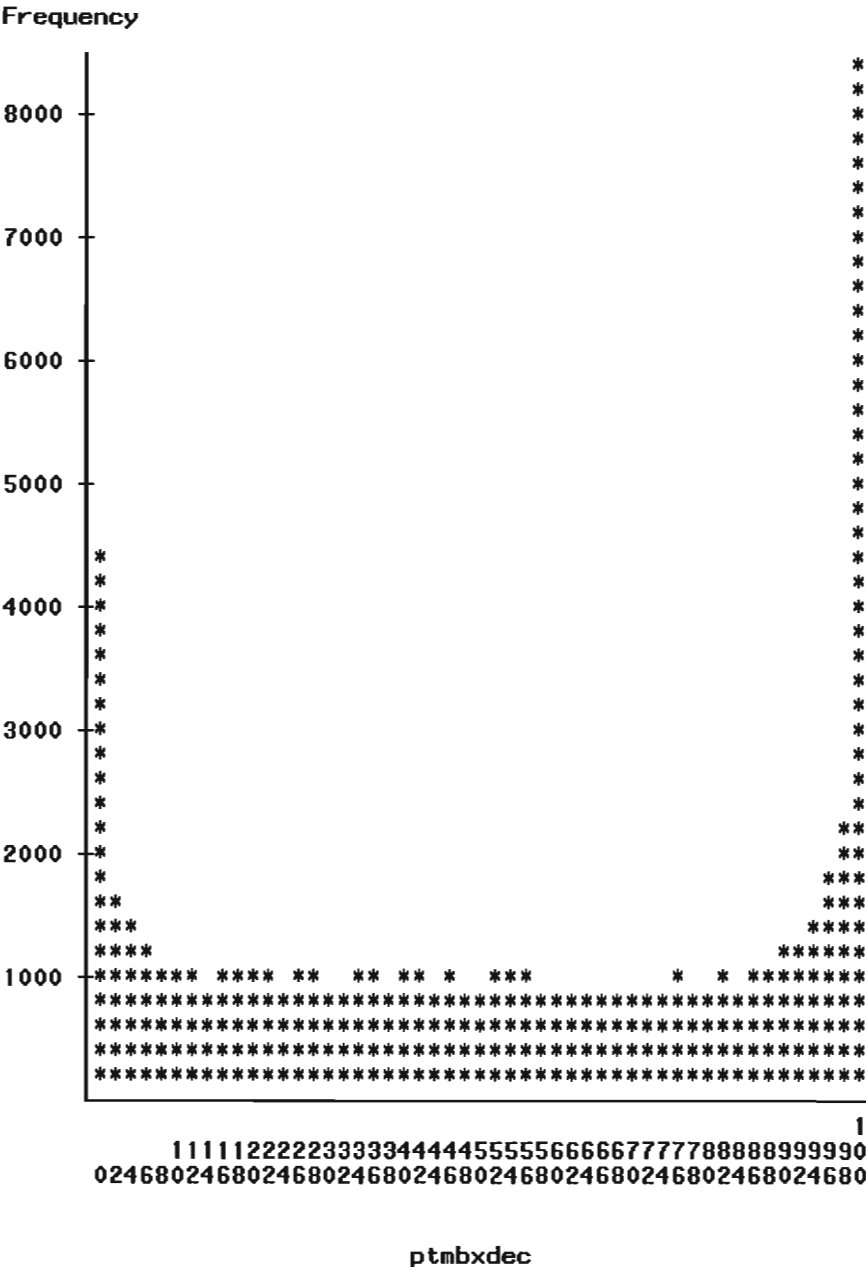
Variable Full Name: Percent Time of Maximum Box X Acceleration (%)
 Abbreviated Name: ptmbxacc



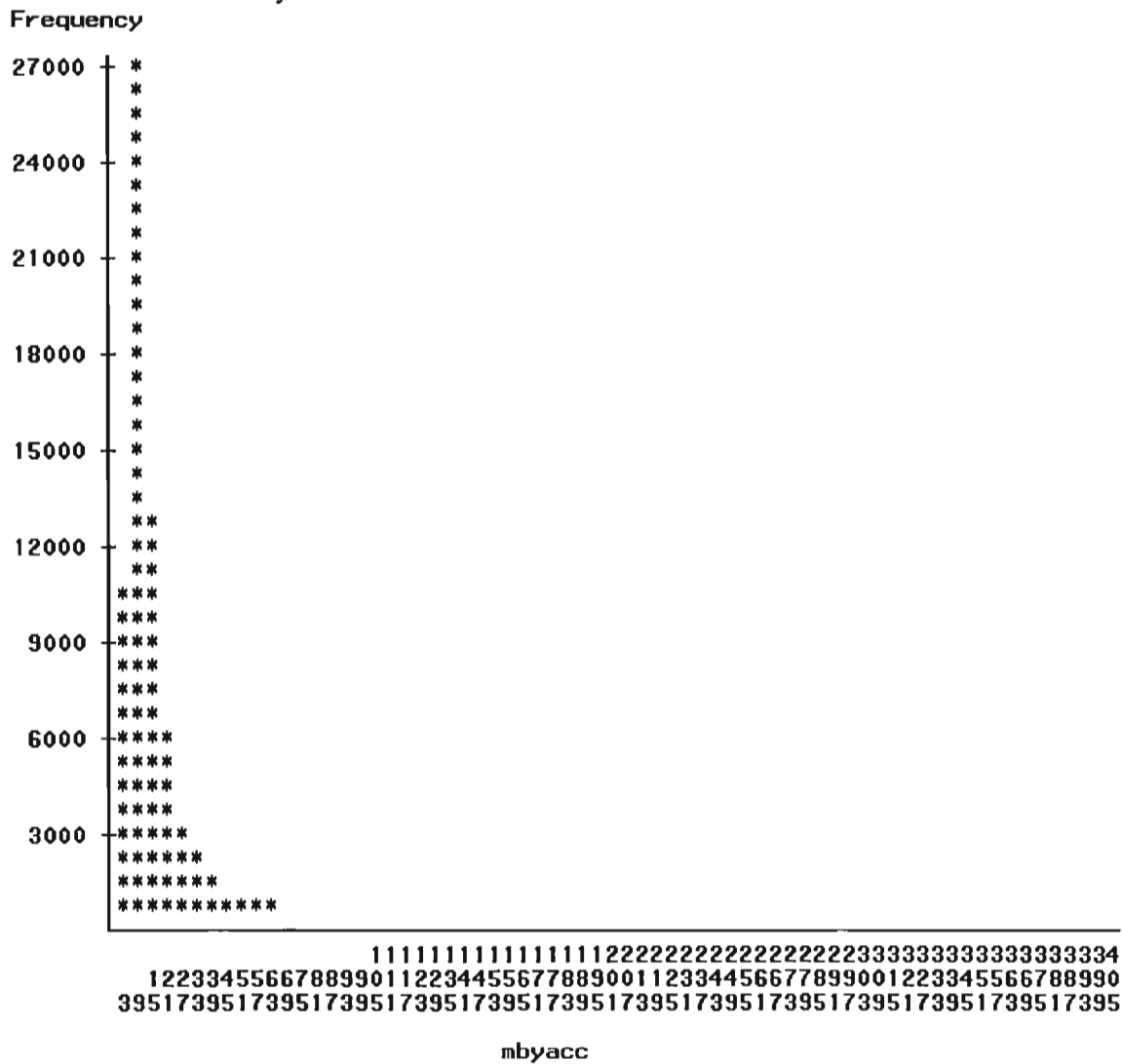
Variable Full Name: Maximum Box X Deceleration (m/s^2)
Abbreviated Name: mbxdec



Variable Full Name: Percent Time of Maximum Box X Deceleration (%)
Abbreviated Name: ptmbxdec

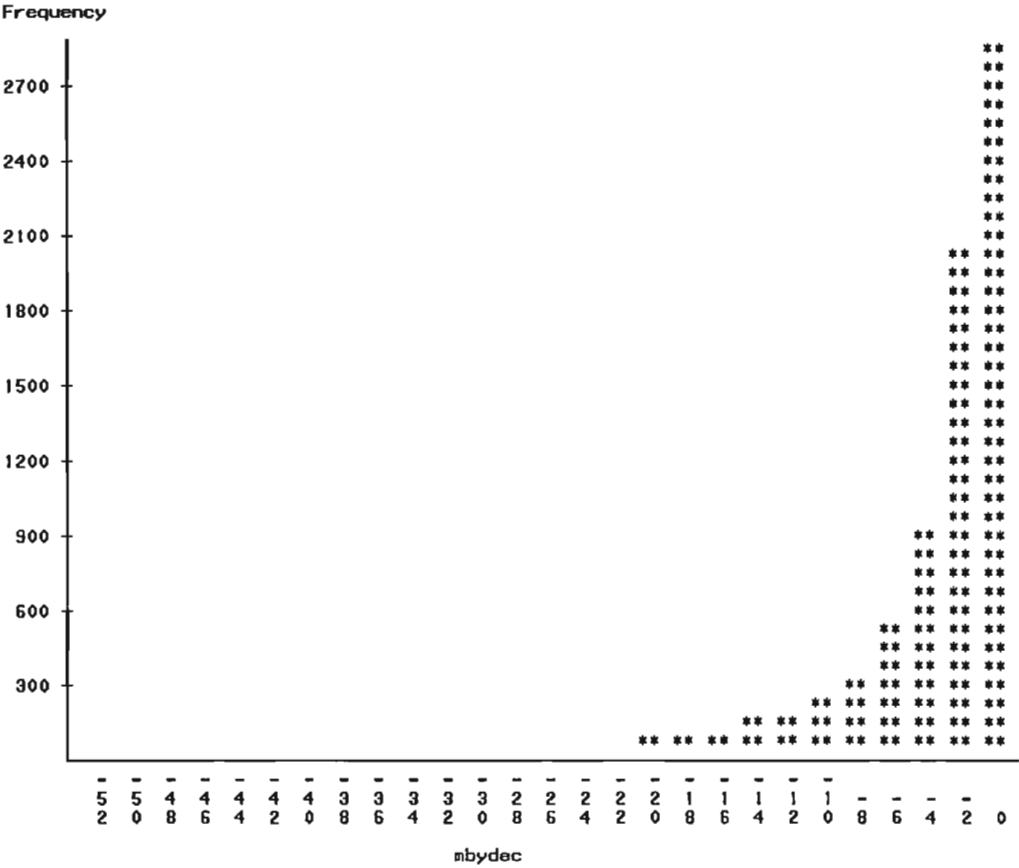


Variable Full Name: Maximum Box Y Acceleration (m/s^2)
Abbreviated Name: mbyacc

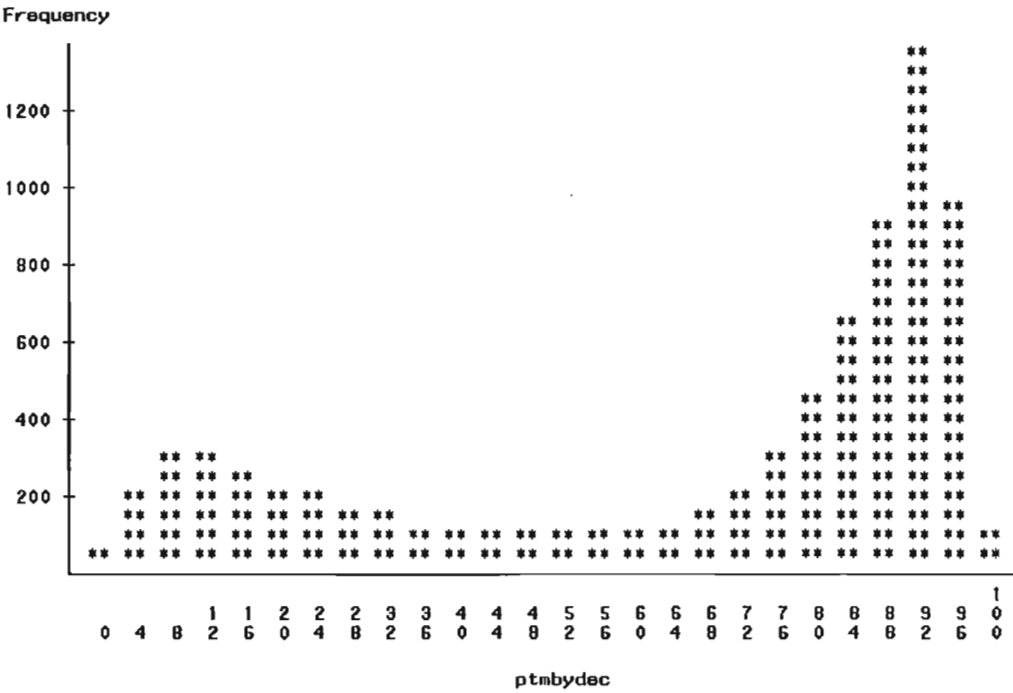




Variable Full Name: Maximum Box Y Deceleration (m/s^2)
Abbreviated Name: mbydec



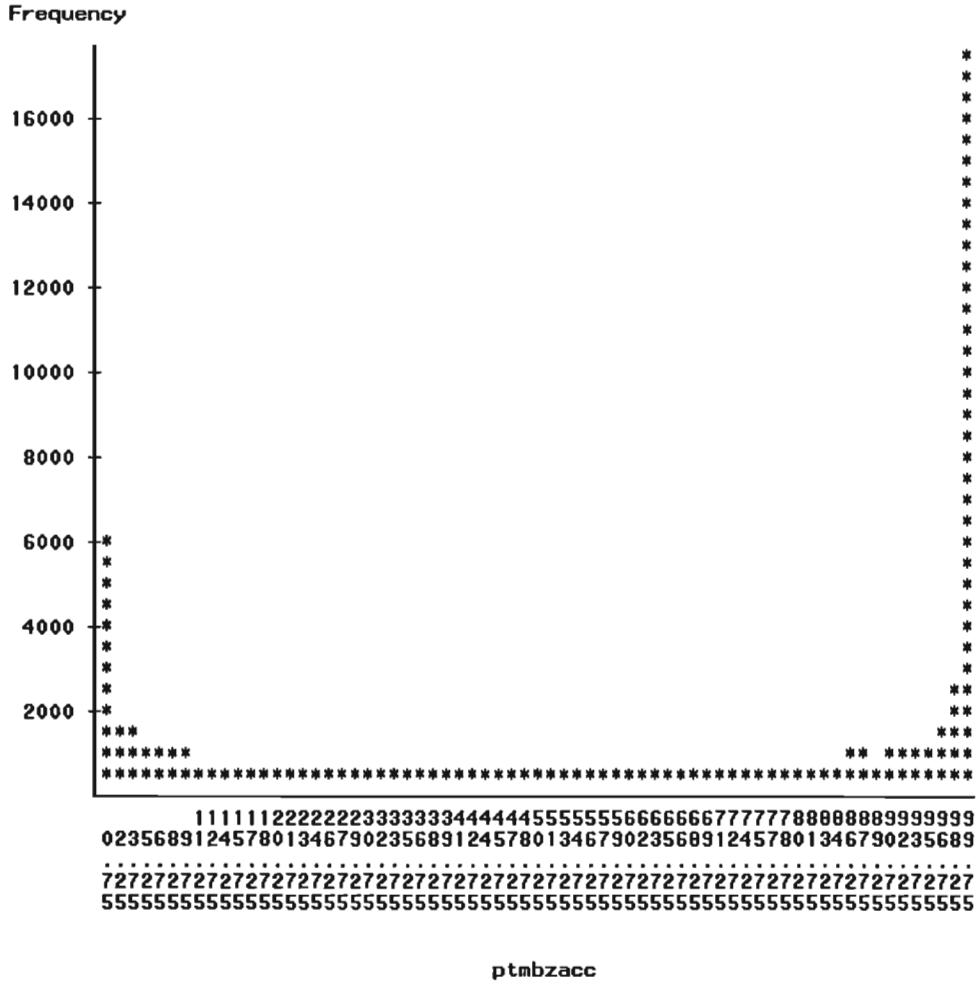
Variable Full Name: Percent Time of Maximum Box Y Deceleration (%)
Abbreviated Name: ptmbydec



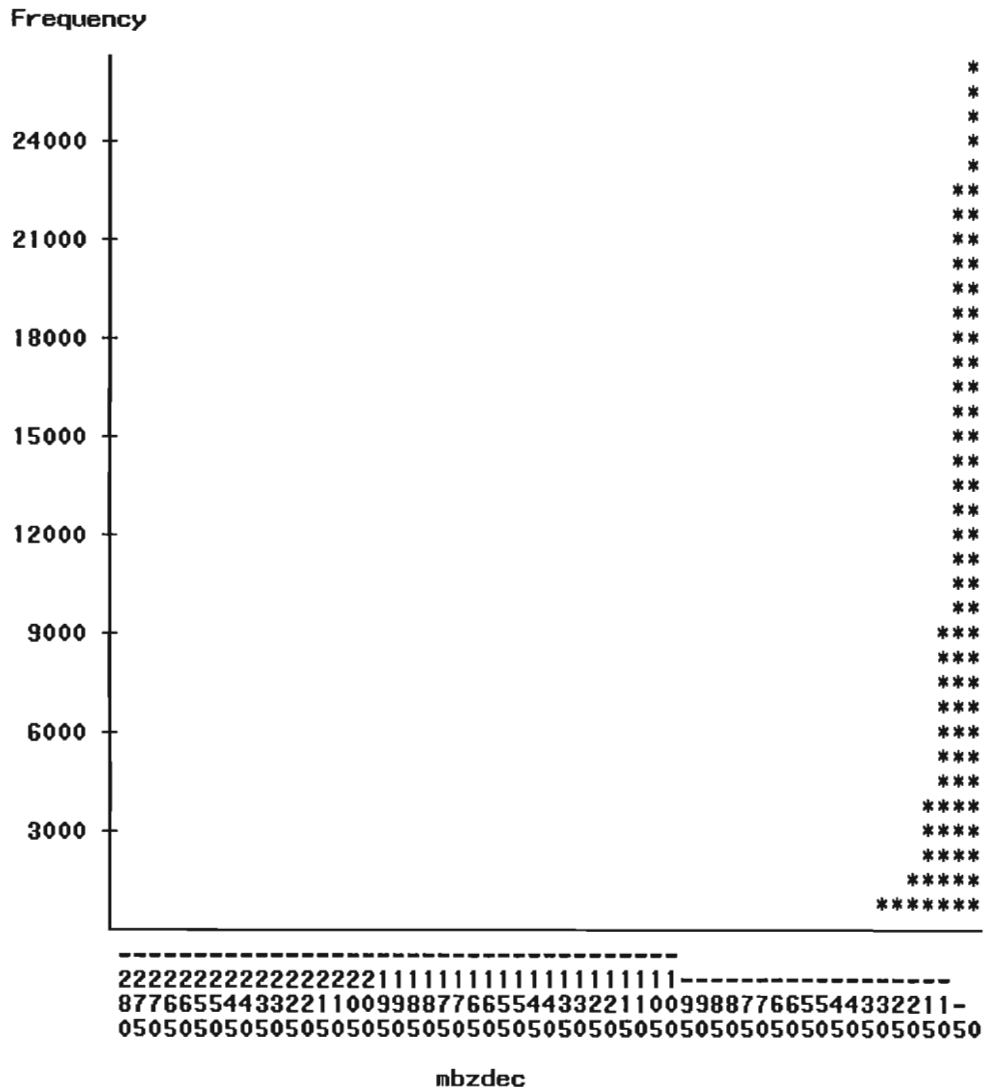
Abbreviated Name: mbzacc



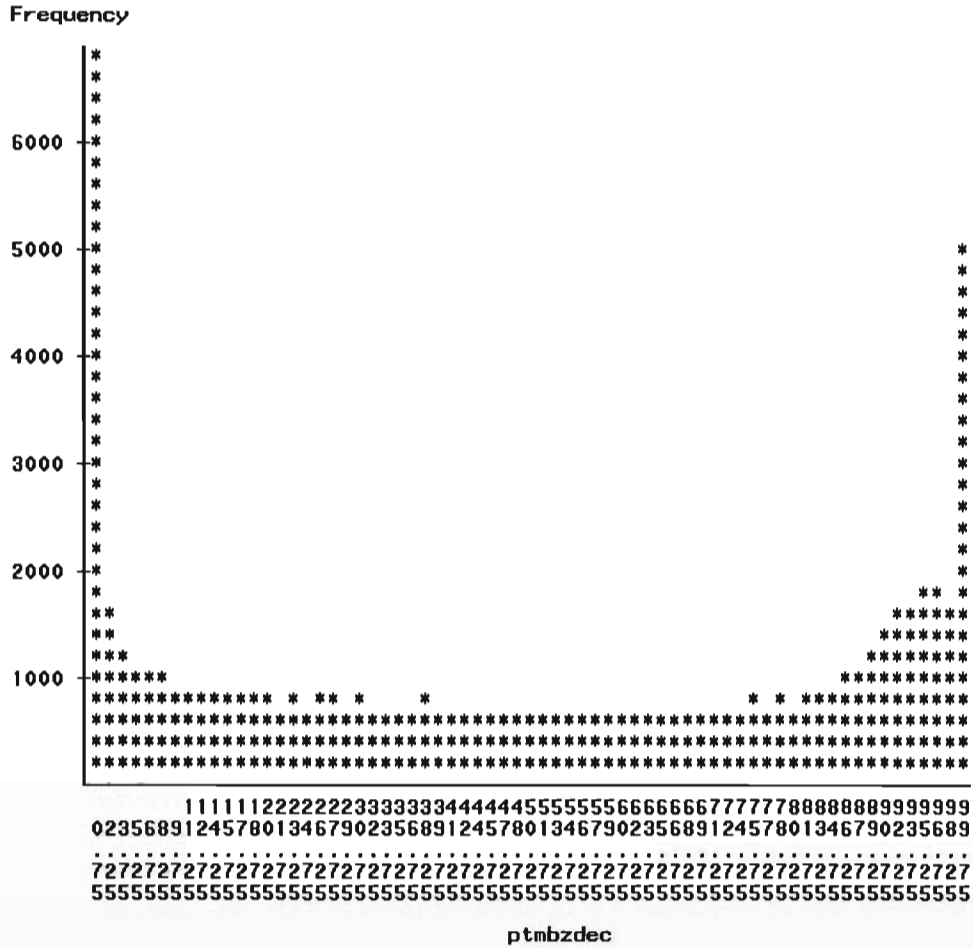
Variable Full Name: Percent Time of Maximum Box Z Acceleration (%)
Abbreviated Name: ptmbzacc



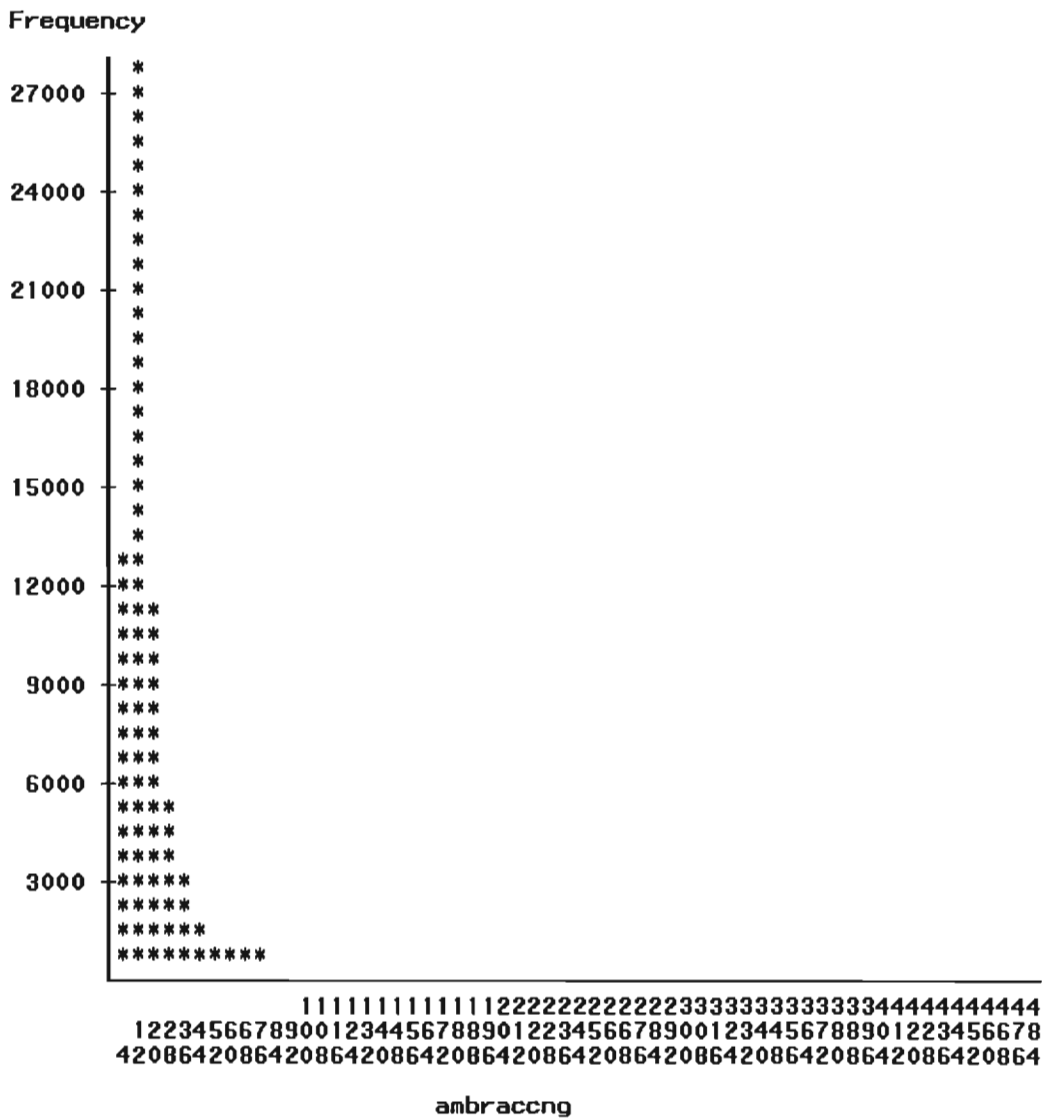
Variable Full Name: Maximum Box Z Deceleration (m/s^2)
Abbreviated Name: mbzdec



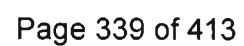
Variable Full Name: Percent Time of Maximum Box Z Deceleration (%)
Abbreviated Name: ptmbzdec



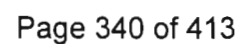
Variable Full Name: Absolute Maximum Box Resultant Acceleration Without Gravity
(m/s^2)
Abbreviated Name: ambraccng



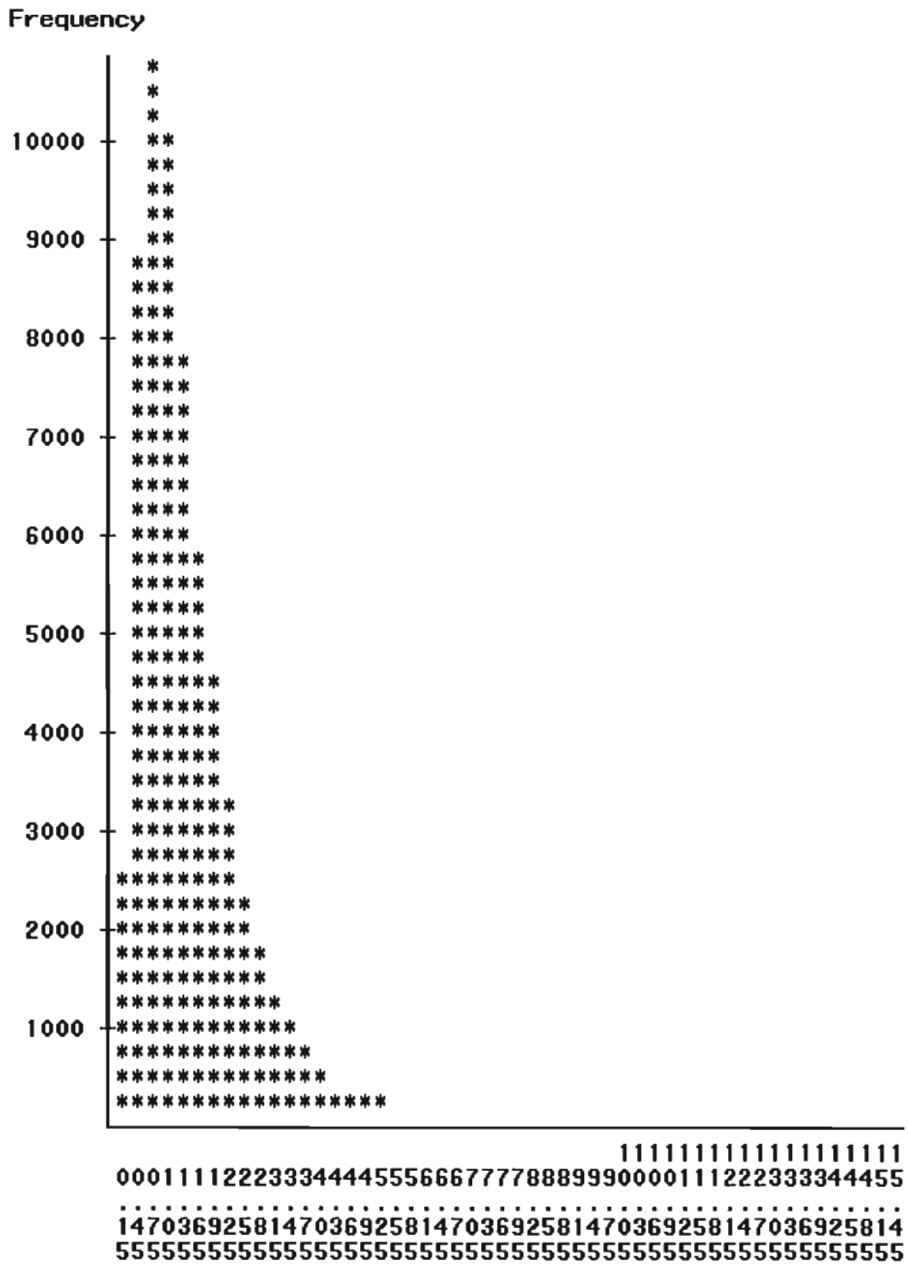
Frequency



Abbreviated Name: RWL

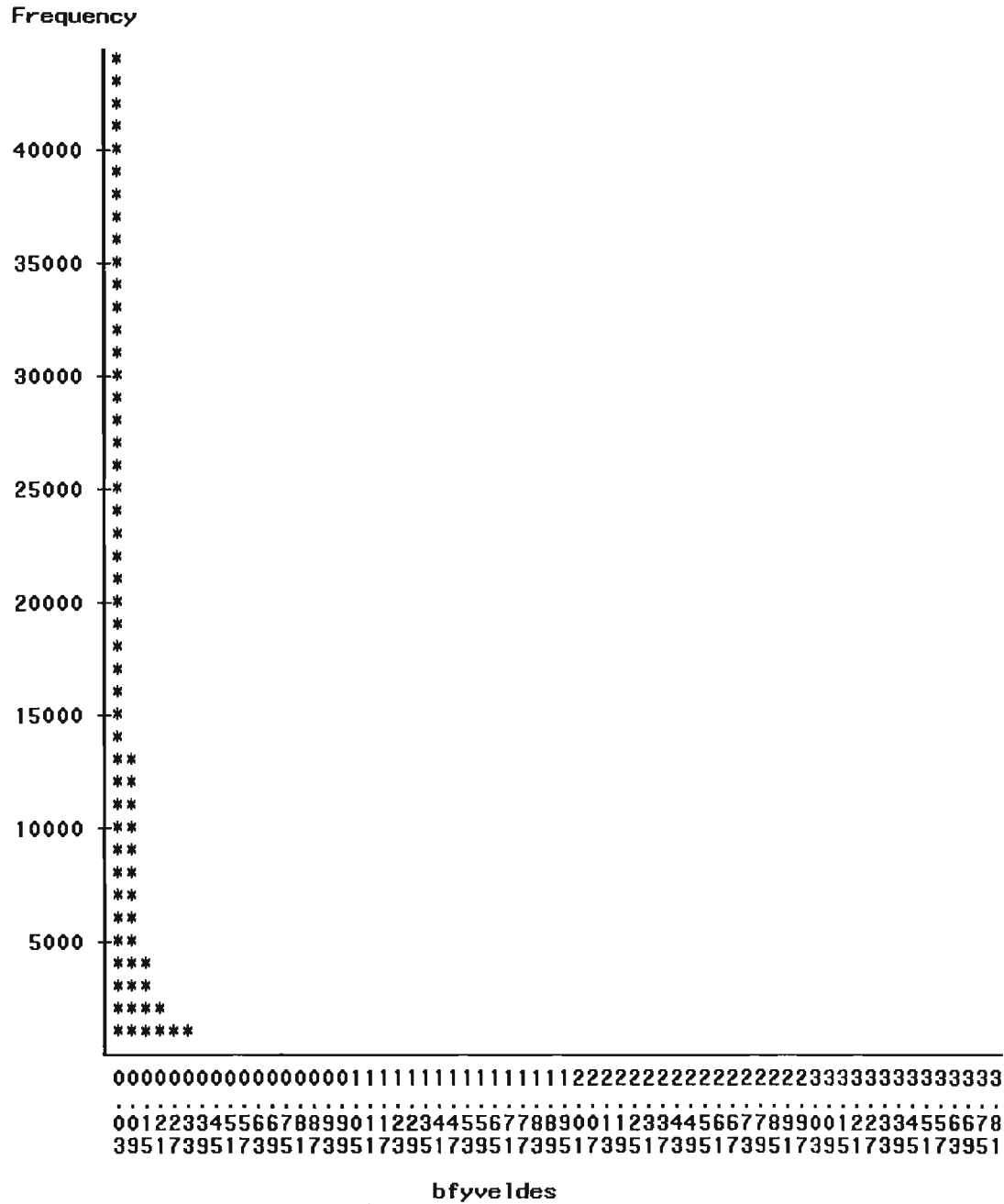


Abbreviated Name: LI



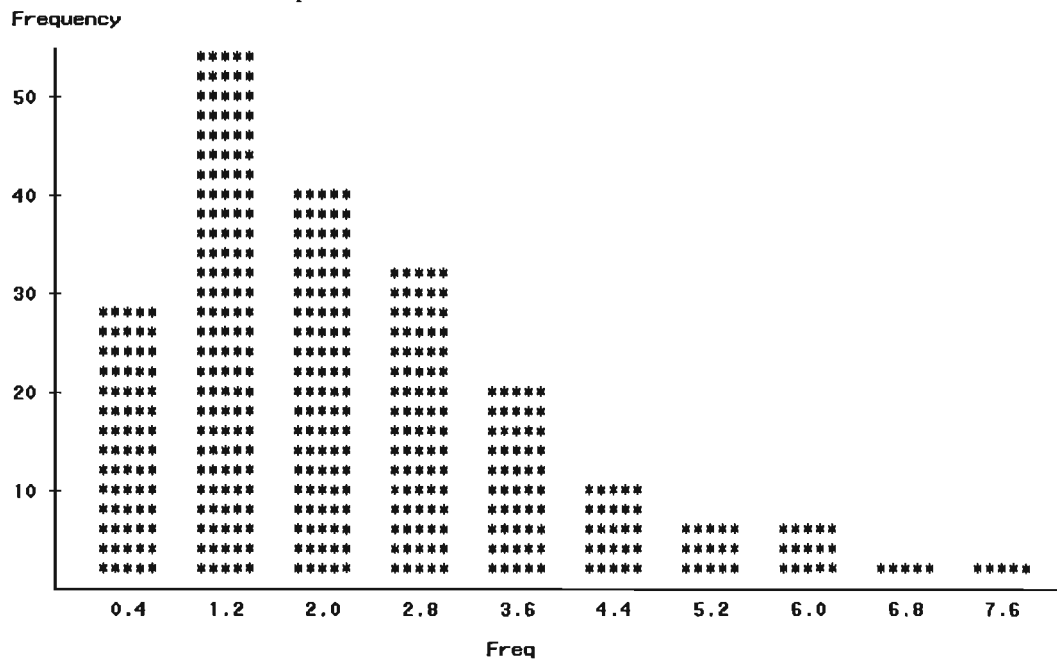
LI

Variable Full Name: Box Forwards Y Velocity at Destination (m/s)
Abbreviated Name: bfyvelde



Variable Full Name: Frequency (Lifts/minute)

Abbreviated Name: freq



APPENDIX A-3

Correlation matrix of all the variables for modeling

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[illegible]

[illegible]

[illegible]

	jmaaxdyz	jmbmaxdyz	jmaroyfym	jmbroyfym	jmbaaxoyfym	jmbraaxoyfym	jmblaaxoyfym	jmbfaoxoyfym	jmbbaaxoyfym	jmbuaxoyfym	jmbdaaxoyfym	jmbtaaxoyfym	jmaaxym	jmbmaxym	jmbpaaxym	jmbbaaxym	jmbraaxym	jmbaaxym	jmbfaoxym	jmbbaaxym
jmbmbxao	0.01678	0.10868	-0.03072	-0.06704	0.25425	0.1187	0.0799	-0.21456	-0.12059	-0.04305	0.06165	-0.18228	0.08077	-0.02684	-0.07171	0.29122	0.12965	0.09736	-0.2209	
jmbmbxdec	-0.27391	-0.16755	-0.05625	0.26321	0.22116	-0.38111	-0.26972	-0.0996	-0.02201	-0.07629	0.07629	0.01537	-0.06269	-0.05317	0.27746	0.24792	-0.37186	-0.2525	-0.10444	
jmbmbxdec	-0.17527	0.08158	-0.23919	-0.13199	-0.31092	-0.11592	-0.26491	-0.14968	0.34522	0.01757	0.18657	-0.04798	-0.19122	-0.24075	-0.13472	-0.31542	-0.12187	-0.26833	-0.14447	
jmbmbxao	0.69071	0.53265	0.63059	0.17991	0.24814	0.30679	-0.28692	0.65685	-0.59348	0.07458	-0.55457	0.03176	0.58457	0.62238	0.18664	0.23603	0.292	-0.28668	0.64727	
jmbmbxao	0.29651	0.50287	0.36471	0.40765	0.22638	-0.2677	0.1804	-0.14919	-0.58484	-0.11128	-0.20315	0.03706	0.39852	0.36696	0.36986	0.21437	-0.27685	0.19442	0.14428	
jmbmbxdec	-0.43506	-0.57906	-0.09567	-0.20167	-0.26931	0.23141	-0.50328	-0.22509	-0.54804	0.04888	-0.35575	-0.57384	-0.08703	-0.1985	-0.2478	0.23036	-0.48933	0.30668	-0.48933	
jmbmbxdec	0.00485	0.28679	0.13299	0.40736	0.05179	-0.21016	0.1404	0.38042	-0.2565	0.15586	-0.25432	0.17968	0.10471	0.13248	0.41327	0.03974	-0.21777	0.14675	0.38068	
jmbmbxao	0.60161	0.52376	0.54369	0.15129	0.17739	0.33938	-0.27637	0.87662	-0.65104	0.54845	-0.63718	-0.02441	0.52489	0.63615	0.16101	0.17246	0.324	-0.27194	0.68577	
jmbmbxao	0.34579	0.69111	0.38894	0.46025	0.21629	0.02112	-0.08722	0.48817	-0.58778	0.1548	-0.48474	0.00042	0.42137	0.38614	0.45255	0.20613	0.01216	-0.07766	0.48253	
jmbmbxdec	-0.44889	-0.40874	-0.4688	-0.34087	-0.15577	-0.502	0.40731	-0.50818	-0.50084	-0.06667	-0.42219	-0.49088	-0.34016	-0.15444	-0.08127	-0.11311	-0.48812	0.41105	-0.2524	
jmbmbxdec	0.02713	-0.18443	0.0402	-0.13802	-0.09637	-0.19334	0.11913	-0.52355	0.29934	-0.39397	0.42446	0.07309	0.06206	-0.13213	-0.08127	-0.11311	-0.48812	0.41105	-0.2524	
jmbmbxao	0.88211	0.53782	0.81172	0.17303	0.24438	0.33769	-0.30813	0.85707	-0.86425	0.41223	-0.81455	0.5727	0.04388	-0.13213	-0.08127	-0.11311	-0.48812	0.41105	-0.2524	
jmbmbxao	0.29079	0.5028	0.32336	0.37887	0.23806	-0.26062	0.1528	0.086	-0.55521	-0.14557	-0.17088	0.00729	0.36681	0.32802	0.35752	0.23138	-0.27215	0.16787	0.84722	
jmbmbxao	-0.01697	0.12149	0.01547	0.45561	0.15249	-0.10849	0.09881	0.19666	-0.26495	-0.08226	-0.18722	-0.12831	-0.06598	0.01478	0.46043	0.16115	-0.12625	0.18883	0.2641	
jmbmbxao	0.51887	-0.03763	0.47731	-0.48374	0.00981	0.1614	-0.15957	-0.18747	-0.06334	0.02811	0.21359	0.04635	0.52813	0.01784	-0.4853	-0.00643	0.16937	-0.16194	0.98074	
jmbmbxao	0.58582	0.57376	0.60871	0.19209	0.22243	0.256	-0.25607	0.59375	-0.34239	-0.57019	0.02762	0.59238	0.80213	0.19374	0.12163	0.23834	-0.24654	0.58238	0.58238	
jmbmbxao	0.37001	-0.33793	0.25315	-0.43711	0.11657	-0.1726	0.01431	-0.32249	-0.03617	0.00643	0.30871	-0.06719	0.16914	0.25102	-0.42695	0.09307	-0.16491	0.01267	-0.32925	
jmbmbxao	0.37504	-0.34187	0.25507	-0.4735	0.11729	-0.17787	0.02257	-0.36426	-0.05681	-0.03422	0.38787	-0.06463	0.17604	0.25335	-0.48449	0.09398	-0.17073	0.02053	-0.37089	
jmbmbxao	0.45521	-0.26139	0.26103	-0.45821	0.17819	-0.06803	-0.0551	-0.28638	-0.06357	-0.07347	0.35451	-0.2369	0.19008	0.25757	-0.46002	0.15238	-0.07843	-0.05327	-0.29301	
jmbmbxao	0.40629	-0.32255	0.26379	-0.4682	0.13566	-0.15083	-0.00175	-0.3433	-0.02785	-0.04345	0.37236	-0.10899	0.18471	0.26127	-0.46209	0.11134	-0.14495	-0.00311	-0.35018	
jmbmbxao	0.37223	-0.33635	0.29134	-0.49564	0.09227	-0.04963	-0.04963	-0.34156	-0.03029	-0.05791	0.34336	-0.03467	0.24142	0.29036	-0.4909	0.06754	-0.15612	0.04995	-0.34887	
jmbmbxao	0.38256	-0.2654	0.27994	-0.46585	0.1178	-0.13172	-0.02066	-0.24013	-0.06557	0.02626	0.27789	-0.05683	0.19908	0.27466	-0.45508	0.06815	-0.12301	-0.02064	-0.24748	
jmbmbxao	0.37522	-0.33245	0.29186	-0.48359	0.0951	-0.18401	0.04499	-0.33402	-0.03341	-0.05204	0.33878	-0.03681	0.23904	0.29031	-0.48834	0.0699	-0.15442	0.04502	-0.34146	
jmbmbxao	0.06897	0.10849	-0.07829	0.16891	-0.01033	-0.33692	0.16163	-0.20298	-0.15383	-0.16892	-0.02512	-0.06078	-0.10395	-0.07968	0.15842	0.01858	-0.34341	0.16419	-0.20219	
jmbmbxao	0.39576	-0.28915	0.28071	-0.48891	0.11381	-0.13943	-0.01143	-0.28172	-0.03813	0.00022	0.34824	-0.04615	0.20535	0.27614	-0.48893	0.04445	-0.1315	-0.01172	-0.28906	
jmbmbxao	0.37857	-0.32928	0.28873	-0.52532	0.09615	-0.16285	0.04608	-0.36891	-0.00766	-0.07237	0.40822	-0.03466	0.24089	0.28766	-0.521	0.07145	-0.15403	0.04503	-0.37816	
jmbmbxao	0.39749	-0.31728	0.295	-0.51751	0.10425	-0.19011	0.05286	-0.35785	-0.00782	-0.08072	0.40473	-0.11052	0.23459	0.28359	-0.51447	0.08466	-0.1825	0.05317	-0.385	
jmbmbxao	0.40088	-0.3121	0.29408	-0.51522	0.10693	-0.18302	0.04393	-0.34936	-0.01251	-0.07489	0.39855	-0.11027	0.23231	0.29228	-0.51177	0.08276	-0.17547	0.04417	-0.35678	
jmbmbxao	0.06655	-0.37578	0.01642	-0.43142	-0.03253	-0.12158	0.04832	-0.43155	0.07245	-0.10702	0.3717	0.28755	0.02363	0.01662	-0.4262	-0.05245	-0.10992	0.05248	-0.43548	
jmbmbxao	0.10352	-0.41272	0.00416	-0.19717	0.01172	-0.3659	0.12035	-0.25428	0.0543	-0.01889	0.22042	-0.09766	-0.14216	0.00133	-0.18187	-0.00959	-0.35842	0.12052	-0.25718	
jmbmbxao	-0.09727	0.34813	0.10206	0.55551	0.02414	0.08976	0.05541	0.39327	-0.11133	0.02857	0.13306	0.10608	0.55007	0.03175	0.08199	0.05416	0.39788	0.39788	0.39788	
jmbmbxao	0.14559	-0.36403	-0.02733	-0.36714	0.03996	-0.25788	0.03659	-0.29444	0.05142	0.01476	0.27762	-0.20347	-0.13994	-0.03177	-0.35475	0.02299	-0.25059	0.03752	-0.29823	
jmbmbxao	-0.15303	0.36217	0.02944	0.37751	-0.03918	0.24044	-0.01448	0.284	-0.04595	0.00645	-0.27316	0.21086	0.14078	0.03441	0.36689	-0.02112	0.23462	-0.01494	0.2879	
jmbmbxao	0.05111	-0.49421	-0.05974	-0.48404	-0.18605	-0.13521	-0.09151	-0.27734	0.09626	0.05791	0.23994	-0.05473	-0.11947	-0.05972	-0.48531	-0.21195	-0.12956	-0.08907	-0.27946	
jmbmbxao	-0.11662	0.30487	0.02711	0.33211	-0.11867	-0.12031	-0.03481	0.24693	-0.02583	-0.04109	0.22282	0.08984	0.12017	0.03195	0.31571	-0.11822	0.09607	-0.0379	0.25331	
jmbmbxao	0.06085	-0.44596	-0.07313	-0.41348	-0.04348	-0.17707	0.01025	-0.27449	0.09008	0.04325	0.24042	-0.10666	-0.17086	-0.07532	-0.03555	-0.05219	-0.16728	0.01348	-0.27781	
jmbmbxao	-0.09923	0.42789	0.04567	0.42167	0.00951	-0.14971	-0.00134	0.29514	-0.04662	-0.03379	-0.2444	0.13039	0.12781	0.04668	0.41477	0.01865	0.13975	-0.00557	0.29908	
jmbmbxao	0.0886	-0.42905	-0.05505	-0.41022	-0.02991	-0.1734	0.00278	-0.28098	0.07494	0.04105	0.25102	-0.111	-0.15059	-0.05708	-0.04184	-0.03967	-0.16469	0.00616	-0.28472	
jmbmbxao	-0.0944	0.42115	0.05235	0.41616	0.01705	-0.24365	0.00033	0.28345	-0.05819	-0.04382	0.11641	0.14119	0.05414	0.41021	0.02589	0.14826	-0.00325	0.2873	0.2873	
jmbmbxao	0.07399	-0.33618	-0.07758	-0.54079	0.07813	0.15203	-0.04441	-0.27658	0.03289	0.08225	0.23459	-0.18962	-0.07843	-0.07778	-0.53378	0.091	0.16873	-0.03703	-0.28246	
jmbmbxao	-0.0875	0.39348	0.08081	0.4499	0.156	0.06086	0.27092	0.214	-0.09858	-0.14229	0.13216	0.15614	0.06406	0.44725	0.17683	0.05636	0.26952	0.21632	0.21632	
jmbmbxao	0.20013	-0.29818	0.04159	-0.38509	0.07541	-0.02414	-0.12366	-0.06238	-0.08639	0.16495	0.06027	-0.11206	-0.04017	0.03554	-0.37479	0.06111	-0.01481	-0.12027	-0.0685	
jmbmbxao	-0.42565	-0.30921	-0.22617	-0.12177	-0.18006	-0.1059	0.18807	0.00113	0.48539	0.16927	-0.08887	-0.25632	-0.21769	0.11207	-0.17912	-0.10649	-0.19177	0.01071	0.01071	
jmbmbxao	0.09422	-0.48107	-0.05098	-0.50954	-0.01456	-0.20262	0.04587	-0.37962	0.1211	-0.01403	0.3877	-0.1454	-0.12935	-0.05287	-0.50075	-0.02482	-0.19263	0.04924	-0.36455	
jmbmbxao	-0.43934	-0.17104	-0.01795	-0.19065	-0.45942	0.50087	0.50087	0.24525	0.23363	-0.26116	0.36078	0.03293	-0.30385	-0.31379	-0.02525	-0.18198	-0.48045	0.51443	-0.24084	
jmbmbxao	0.09521	-0.42647	-0.05373	-0.4997	-0.02383	-0.13765	-0.0185	-0.32143	0.08238	0.03843	0.29964	-0.13823	-0.11444	-0.05607	-0.491	-0.03235	-0.12608	-0.01493	-0.32634	
jmbmbxao	0.07326	-0.33919	-0.07809	-0.54335	0.07519	0.15008	-0.04489	-0.27714	0.03712	0.08312	0.2361	-0.18892	-0.08	-0.07834	-0.53596	0.08778	0.16687	-0.03771	-0.28303	
jmbmbxao	-0.08667	0.39532	0.0791	0.44979	0.1534	0.05931	0.26943	0.21318	-0.09715	-0.14304	-0.22331	0.13138	0.15507	0.08237	0.44691	0.17411	0.05466	0.26802	0.21555	
jmbmbxao	0.19455	-0.30747	0.03752	-0.38705	0.0724	-0.02499	-0.12165	-0.06347	-0.0784	0.16527	0.06271	-0.1148	-0.04552	0.03154	-0.37871	0.05804	-0.01555	-0.11821	-0.06949	
jmbmbxao	-0.42554	-0.3088	-0.2258	0.12361	-0.17926	-0.10683	0.18977	0.00143	0.48429	-0.07846	0.16878	-0.08924	-0.25596	-0.21732	0.11384	-0.17843	-0.10945	0.19346	0.01101	
jmbmbxao	0.25102	-0.2352	0.06642	-0.51613	0.06861	0.06014	-0.18001	-0.15773	-0.06492	0.17177	0.18373	-0								

mbg8	0.02894	-0.19148	-0.29659	-0.05514	0.25123	-0.37105	0.07538	0.08045	0.09174	-0.06234	-0.27459	-0.0509	-0.27119	-0.18246	-0.09167	-0.03171	0.21805	0.14476	-0.07441	0.22867	0.11434
mbg7	-0.11111	0.0084	-0.12223	0.02135	-0.12989	-0.23271	0.2116	0.35718	0.03024	-0.25142	-0.2116	0.24261	0.12061	-0.27459	-0.0509	-0.27119	-0.18246	-0.09167	-0.03171	0.21805	0.14476
mbg6	-0.15143	-0.12496	-0.2817	-0.0862	0.30128	-0.25142	0.03024	0.01429	-0.08049	-0.31874	-0.14476	-0.28591	-0.12829	-0.10616	-0.13239	0.22312	0.2946	-0.2564	-0.37044	-0.0156	-0.10493
mbg5	0.02894	-0.19148	-0.29659	-0.05514	0.25123	-0.37105	0.07538	0.08045	0.09174	-0.06234	-0.27459	-0.0509	-0.27119	-0.18246	-0.09167	-0.03171	0.21805	0.14476	-0.07441	0.22867	0.11434
mbg4	-0.03937	-0.10091	-0.25642	-0.29096	-0.02136	0.24974	-0.34882	-0.10188	0.038	0.0775	-0.41895	-0.19634	-0.15699	-0.19765	-0.07328	0.24716	-0.37044	-0.0156	-0.10493	-0.0156	-0.10493
mbg3	-0.07216	0.2598	-0.01101	0.23735	-0.11161	-0.05435	0.13521	0.38649	-0.1743	0.07751	-0.31398	-0.0547	-0.0153	-0.24411	0.12472	-0.05144	0.13681	-0.2564	-0.37044	-0.0156	-0.10493
mbg2	-0.27103	-0.15614	-0.16161	0.04609	0.03964	0.02795	0.06397	0.05214	0.03976	-0.15807	-0.13295	-0.03195	-0.1179	-0.15466	0.06313	0.02838	0.03117	0.06395	0.05092	0.05092	0.05092
mbg1	-0.2346	0.06152	-0.38787	-0.04604	-0.1066	-0.15186	-0.07703	-0.00408	-0.00779	-0.02302	-0.05529	-0.2098	-0.28471	-0.03087	-0.05735	-0.08461	-0.14922	-0.21128	-0.00449	-0.00449	-0.00449
mbc8	-0.13318	0.06789	-0.03422	-0.09967	-0.14196	0.04718	-0.02204	0.03051	-0.00379	-0.10373	0.02865	0.1045	-0.02274	-0.03087	-0.1063	-0.16329	0.04683	0.00318	0.00326	0.00326	0.00326
mbc7	-0.06452	-0.30101	-0.05342	-0.0561	0.02896	-0.11351	0.04445	-0.00537	-0.09909	-0.14156	-0.04406	-0.09144	-0.01436	-0.05416	-0.06263	-0.01207	-0.11205	0.05906	-0.00564	-0.00564	-0.00564
mbc6	0.19171	0.28804	0.23513	0.19453	-0.15989	-0.13739	-0.10358	-0.00855	-0.05649	-0.15614	-0.11722	0.16287	0.21613	0.14781	0.09726	-0.19491	0.0075	-0.06835	-0.24916	-0.24916	-0.24916
mbc5	-0.03156	-0.27023	-0.19156	-0.56396	-0.07797	-0.05399	-0.14675	-0.28163	0.03107	-0.08682	-0.13074	-0.19224	-0.56291	-0.10297	-0.18071	-0.06438	-0.06962	-0.03258	-0.03258	-0.03258	-0.03258
mbc4	0.38218	0.22576	0.22576	-0.2649	-0.19941	-0.07235	-0.07151	-0.29126	-0.16583	-0.01051	-0.05413	0.13429	0.21888	-0.24071	0.18071	-0.06438	-0.06962	-0.03258	-0.03258	-0.03258	-0.03258
mbc3	-0.40119	-0.02287	0.24238	-0.23179	-0.20675	-0.04766	-0.06567	-0.07399	-0.06184	-0.02513	-0.33516	-0.28216	-0.16113	-0.18086	-0.03031	-0.04984	0.13913	0.22782	-0.06028	-0.06028	-0.06028
mbc2	0.39562	-0.07614	0.23487	-0.2608	0.23079	-0.0567	-0.06184	-0.02513	-0.06184	-0.02513	-0.33516	-0.28216	-0.16113	-0.18086	-0.03031	-0.04984	0.13913	0.22782	-0.06028	-0.06028	-0.06028
mbc1	-0.03311	-0.03311	-0.03311	-0.03311	-0.03311	-0.03311	-0.03311	-0.03311	-0.03311	-0.03311	-0.03311	-0.03311	-0.03311	-0.03311	-0.03311	-0.03311	-0.03311	-0.03311	-0.03311	-0.03311	-0.03311

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	jmbaaamsdm	jmbuasmsdm	jmbdaasrmsd	jmbtaasm	jnsamsm	jnpbmymdm	jmbuaemysm	jmbreaemysm	jmbiaaemysm	jmbfaemysm	jmbbaemysm	jmbusaemysm	jmbdaemysm	jmbtaemysm	jnsadm	jnpbmmdm	jmbaamsdm	jmbraamsdm	jmbfmaamsdm
jpldyabycc	-0.28268	0.12046	0.01355	-0.05937	0.36118	-0.06364	0.31437	-0.07582	0.01933	-0.09467	-0.10936	-0.06644	0.08582	-0.1349	0.38132	-0.10537	0.1814	-0.00264	-0.1114
jplfdxtacc	-0.35042	0.1503	-0.06568	-0.04032	0.36854	-0.06065	0.32325	-0.05256	0.01604	-0.03814	-0.13245	-0.02554	0.01081	-0.11245	0.39882	-0.05248	0.18881	0.02359	-0.11406
jpldfdracgm	-0.30258	0.12457	0.00261	-0.06367	0.3486	-0.05373	0.31137	-0.05952	0.00987	-0.09174	-0.11093	-0.05998	0.07426	-0.13827	0.37505	-0.10514	0.17768	0.01116	-0.1216
fjrec	0.19802	-0.01097	0.31945	-0.09124	-0.22137	0.03796	-0.07832	0.1991	-0.24048	-0.38917	0.01898	-0.08922	0.30772	-0.12259	-0.10652	-0.53923	-0.13341	0.18	-0.29998
mibcontrol	-0.08716	-0.04837	-0.15094	0.11662	0.15497	0.04252	-0.38605	0.05765	-0.18029	0.23948	0.08835	0.02811	-0.13094	0.0653	0.2129	-0.00448	-0.38543	-0.0102	-0.02384
mibcosss	0.01769	-0.07905	-0.12217	0.16938	0.01258	0.08099	-0.0902	0.23877	-0.19203	0.22423	0.01058	0.15274	-0.22209	0.17686	0.1106	0.14528	-0.06386	0.1831	-0.16439
mibscow	-0.08023	-0.11148	-0.03977	-0.08664	-0.0508	0.03608	0.06946	-0.07436	0.01047	0.01635	0.14413	-0.03481	-0.0659	-0.06019	-0.05728	0.0547	0.04877	-0.09349	0.04578
mibsatts	0.03419	-0.09015	0.0283	0.11105	-0.10844	0.08145	-0.11792	-0.05722	-0.12457	0.06003	-0.10298	0.00446	0.01395	0.09242	-0.06488	-0.03871	-0.10196	0.00442	0.00798
magebg	0.05182	-0.02491	-0.05727	-0.20368	-0.37913	0.13436	-0.02467	0.24289	-0.23154	0.0778	-0.08693	0.14208	-0.12991	-0.10867	-0.35167	-0.04553	-0.04105	0.21385	-0.2291
mimbmb	-0.01178	0.19618	-0.12766	-0.05383	-0.21395	-0.0256	0.09986	0.07185	0.0512	0.09894	0.13672	-0.134	-0.04774	-0.27908	-0.08069	0.00399	-0.00199	-0.03137	0.04851
mnbq3	-0.24849	0.08536	-0.31891	-0.06794	0.0478	-0.04149	0.16805	-0.20177	0.18271	0.33983	-0.10615	0.0992	-0.29018	-0.00627	0.06671	0.40583	0.21581	-0.13402	0.25725
mnbql	0.09313	0.03048	0.08681	-0.4099	-0.16315	0.06157	-0.02035	0.32184	-0.35532	-0.04626	-0.25553	0.15891	-0.29043	-0.37787	-0.24545	-0.30227	-0.04114	0.32893	-0.40598
mnbq5	0.12434	0.04953	0.06977	-0.38914	-0.12081	0.10696	-0.0381	0.26822	-0.35991	-0.05121	-0.22723	0.12202	0.0284	-0.35887	-0.18939	-0.30384	-0.06747	0.27965	-0.38416
mnbq6	0.04819	0.07235	-0.07616	-0.31402	-0.28733	0.18463	-0.06908	0.05059	-0.24399	0.09231	-0.23072	0.12202	0.0284	-0.35887	-0.18939	-0.30384	-0.06747	0.27965	-0.38416
mnbq7	-0.06905	0.28885	-0.26578	0.15242	-0.06981	-0.17152	-0.08545	0.12978	-0.14518	0.35408	-0.00246	0.33882	-0.24433	0.19806	-0.10943	0.09468	-0.14022	0.08999	-0.09233
mnbq8	-0.27047	-0.03828	-0.27061	-0.18507	-0.03862	-0.12018	0.14468	-0.147	0.32467	0.06786	-0.1291	-0.11563	-0.24621	-0.20166	-0.07991	0.0845	0.14877	-0.12191	0.34479

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	mbfaamxdm	mbbaamxdm	mbuaamxdm	mbdaamxdm	mbtaamxdm	mbmamxdm	mbptamxdm	mbaamydm	mbraamydm	mblaamydm	mbfaamydm	mbbaamydm	mbuaamydm	mbdaamydm	mbtaamydm	mbmamxdm	mbptamxdm	mbaamxydm	mbraamxydm
jalpdyacc	0.25378	0.04851	0.21877	-0.1648	-0.06311	0.46571	-0.01748	0.30753	-0.02183	-0.02846	0.22821	-0.00178	0.18621	-0.01158	-0.11407	0.36832	-0.11069	0.20275	-0.00361
jalpdyacc	0.32865	0.05312	0.29904	-0.22001	-0.04902	0.47008	0.0307	0.31928	-0.0062	-0.02591	0.30282	-0.01224	0.26478	-0.08254	-0.09317	0.40385	-0.05662	0.20806	0.02255
jalpdyaccgn	0.25831	0.05294	0.22672	-0.17447	-0.06994	0.45542	-0.00501	0.3048	-0.00421	-0.03937	0.23436	-0.00546	0.19506	-0.02488	-0.11883	0.38189	-0.11006	0.19784	0.01025
jfreq	-0.32791	0.03669	-0.30707	0.07113	-0.13745	-0.09222	-0.20226	-0.09307	0.27637	-0.30087	-0.27821	0.15495	-0.2885	0.18274	-0.142	-0.10601	-0.54898	-0.13624	0.17745
mbcontrol	0.17146	-0.2367	0.12884	-0.18903	0.08356	0.16422	0.18254	-0.35377	-0.03811	-0.14835	0.14855	-0.07702	0.0839	-0.16589	0.05484	0.21175	0.02035	-0.361	-0.00184
mbabosa	0.04653	-0.21537	0.02785	-0.19928	0.11513	0.02004	0.15738	-0.04531	0.24773	-0.19122	0.07289	0.01136	0.0405	-0.24976	0.13815	0.10613	0.1609	-0.07783	0.18998
mbacow	0.01834	-0.05087	-0.00924	0.05131	-0.11399	-0.05643	0.20529	0.09145	-0.05628	-0.02168	0.03244	0.01568	-0.00211	-0.07222	-0.08262	-0.05724	0.06698	0.09409	-0.09272
mbaata	-0.02279	-0.18752	-0.04362	-0.01993	0.09355	-0.1192	0.0919	-0.09045	0.03596	-0.08426	-0.01882	-0.04779	-0.04715	-0.04351	0.0762	-0.06907	-0.02307	-0.09918	-0.00027
mageb	-0.0706	0.01532	-0.06927	-0.00568	-0.22372	-0.34015	0.17511	0.00054	0.27183	-0.26121	0.00712	-0.01813	-0.02858	-0.15267	-0.14107	-0.5474	-0.02673	-0.0406	0.23263
mbmb	-0.19676	-0.07157	-0.13782	0.04964	-0.04675	-0.3122	-0.06393	-0.07424	-0.01138	0.05517	-0.12252	0.04955	-0.04617	-0.09828	-0.03097	-0.28389	-0.09951	0.00013	-0.03827
mbq3	0.443	0.09455	0.40984	-0.18364	-0.07227	0.04619	0.28937	0.18374	-0.24374	0.2556	0.40876	0.04669	0.37825	-0.17394	-0.01216	0.06975	0.4168	0.22615	-0.11668
mbq4	-0.13045	-0.15388	-0.08938	0.01434	-0.4228	-0.13638	0.01193	-0.04076	0.37812	-0.39154	-0.04092	-0.10614	-0.03986	-0.06313	-0.38673	-0.23714	-0.29453	-0.06517	0.33312
mbq5	-0.10931	-0.18207	-0.07285	-0.00729	-0.37981	-0.11027	-0.06394	-0.05311	0.31349	-0.35837	-0.03968	-0.12673	-0.03366	-0.04787	-0.38478	-0.18334	-0.29402	-0.08042	0.29002
mbq6	-0.10357	-0.14391	-0.04781	-0.06367	-0.32337	-0.27879	0.11091	-0.07189	0.32734	-0.20664	0.00458	0.03661	0.04185	-0.18514	-0.2572	-0.29655	-0.16584	-0.10484	0.32919
mbq7	0.23033	-0.01618	0.26844	-0.08566	0.15902	-0.08647	0.01808	-0.08354	0.05243	-0.08132	0.26893	0.08352	0.28814	-0.2017	0.20385	-0.10568	0.08866	-0.14198	0.10584
mbq8	0.05322	0.05797	0.06653	-0.07095	-0.14914	-0.1094	0.01703	0.12957	-0.13814	0.35043	0.05832	0.03036	0.08913	-0.14045	-0.17727	-0.08285	0.08397	0.17353	-0.10758

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	jmbaamyldm	jmbaamyldm	jmbaamyldm	jmbaamyldm	jmbaamyldm	jmbaamyldm	jmbaamyldm	jmbaamyldm	jmbaamyldm	jmbaamyldm	jmbaamyldm	jmbaamyldm	jmbaamyldm	jmbaamyldm	jmbaamyldm	jmbaamyldm	jmbaamyldm	jmbaamyldm
jmbaamyldm																		
jmbaamyldm																		
jmbaamyldm																		
jmbaamyldm	1.000	1.000																
jmbaamyldm	-0.11319	-0.29341																
jmbaamyldm	0.16871		1.000															
jmbaamyldm	-0.12055	-0.28908		1.000														
jmbaamyldm	0.22314	-0.68439	0.34975		-0.85373	1.000												
jmbaamyldm	0.10936	-0.03036	0.10011	-0.08046	0.0947		1.000											
jmbaamyldm	-0.0539	0.21866	-0.27519	0.17505	-0.2219	0.19198		1.000										
jmbaamyldm	-0.06649	0.58712	-0.3343	0.53747	-0.44161	0.0399			1.000									
jmbaamyldm	-0.09859	0.55712	-0.254	0.53778	-0.28803	-0.08476	0.09028	0.26185		1.000								
jmbaamyldm	0.20015	0.25129	0.07112	0.18495	-0.05572	-0.10984	0.05906	0.18992	0.35177		1.000							
jmbaamyldm	-0.63918	0.13339	-0.18017	0.17447	-0.38762	-0.21519	0.18458	0.11016	0.07624	0.10312		1.000						
jmbaamyldm	-0.03884	-0.03884	0.14364	-0.04813	0.16452	0.15741	-0.08476	-0.01681	-0.01675	0.1968			1.000					
jmbaamyldm	-0.13545	-0.30133	-0.30133	-0.66935	-0.04706	0.21574	0.57573	0.57568	0.25225	0.16195	-0.06385			1.000				
jmbaamyldm	0.00865	-0.17373	-0.16996	0.22725	0.14464	-0.16665	-0.2386	-0.1362	0.07039	0.03659	0.01949	-0.19303			1.000			
jmbaamyldm	-0.138	-0.30558	-0.30558	-0.6526	-0.09516	0.17895	0.53581	0.55882	0.1826	0.20257	-0.06771				1.000			
jmbaamyldm	0.22039	-0.80094	0.33112	-0.8743	0.02993	-0.1518	-0.37678	-0.30492	-0.02688	-0.31237	0.13681	-0.89322	0.21468			-0.68574	1.000	
jmbaamyldm	0.10538	0.04061	0.11132	-0.00814	0.04217	0.16293	0.03543	-0.04374	-0.11494	-0.23185	0.17286	0.02508	0.16063	-0.02387		-0.03664		1.000
jmbaamyldm	-0.01731	0.59489	-0.34076	0.54587	-0.44274	0.03727	0.03727	0.26571	0.18868	0.11597	-0.02577	0.58345	-0.24191		0.54431	-0.37898	0.03295	
jmbaamyldm	-0.06957	0.55759	-0.26359	0.53544	-0.30079	-0.09348	0.10933	0.28006	0.03497	0.05685	0.00771	0.57481	-0.15896	0.55439	-0.32545	-0.04654		
jmbaamyldm	0.20461	0.26016	0.06301	0.18606	-0.08811	0.08854	0.22278	0.3527	0.09209	0.19935	0.26482	0.06193	0.18541		-0.00852	-0.089		
jmbaamyldm	-0.64742	0.12613	-0.19042	0.17043	-0.38996	-0.20623	0.18298	0.10308	0.07044	0.09025	-0.64817	0.15492	0.02634	0.19762	-0.31437	-0.22307		
jmbaamyldm	-0.03572	-0.03572	0.1477	-0.04313	0.15493	0.15198	-0.08856	-0.01961	-0.02276	0.20618	-0.6377	-0.05833	0.01743	-0.06168	0.13171	0.16622		
jmbaamyldm	-0.13091	-0.30222	-0.30222	-0.6688	-0.04423	0.21746	0.57732	0.56885	0.25255	0.15733	-0.06114	-0.05855	-0.19461	-0.05816	-0.89403	0.02701		
jmbaamyldm	0.00273	-0.23903	-0.22632	0.26472	0.14555	-0.1795	-0.20466	0.0019	-0.02856	0.00306	-0.25547	-0.05816	-0.24452	0.24497	0.15977			
jmbaamyldm	-0.1415	-0.29689	-0.29689	-0.65175	-0.09648	0.17097	0.53034	0.55314	0.18364	0.2016	-0.07068	-0.17979	-0.65688	-0.68764	-0.02432			
jmbaamyldm	0.24512	-0.68199	0.35512	-0.68331	0.03452	-0.16558	-0.37789	-0.29031	-0.00781	-0.32952	0.16541	-0.68642	0.24536	-0.65688	-0.0293	-0.03002		
jmbaamyldm	0.10401	0.04254	0.11776	-0.00546	0.04917	0.03268	0.15748	-0.03991	-0.11152	-0.02842	0.1725	0.0269	0.16896	-0.02078	-0.0293	-0.03614		
jmbaamyldm	-0.06528	0.25736	-0.33152	0.21553	-0.24681	-0.02684	0.03452	0.11898	0.09978	0.19219	-0.106	0.24728	-0.20919	0.21628	-0.15633	-0.0636		
jmbaamyldm	0.09272	0.04148	0.00998	-0.01925	0.07318	-0.07359	0.23652	0.12005	0.0204	-0.02876	-0.20303	0.13641	0.02508	0.08124	0.00645	-0.07785		
jmbaamyldm	0.32768	0.37401	0.03601	0.34246	-0.13621	0.3759	-0.08361	0.15038	0.29215	0.04146	-0.4142	0.44485	0.34902	0.0137	0.32746	-0.20083	0.44718	
jmbaamyldm	0.07292	0.38141	-0.25459	0.38978	-0.4367	0.02048	-0.72362	-0.71507	0.19081	0.11231	0.11968	0.07275	0.37813	-0.15406	0.38304	-0.04651		
jmbaamyldm	0.08341	0.35833	-0.24541	0.37013	-0.43724	0.01598	-0.72142	-0.70163	0.17686	0.0934	0.11966	0.08053	0.35533	-0.15232	0.3636	-0.38789	0.04345	
jmbaamyldm	-0.13033	-0.13304	0.04934	-0.08407	0.11291	0.15614	-0.08778	-0.19006	-0.23491	-0.15874	-0.17737	-0.14668	0.12202	-0.09243	0.0946	0.1612		
jmbaamyldm	0.21233	0.26176	-0.04661	0.22718	-0.19074	0.26423	-0.07624	-0.05501	-0.02519	0.05494	-0.15036	0.17414	0.2552	-0.12623	0.20639	-0.16424	0.25685	
jmbaamyldm	-0.09416	-0.16617	0.0488	0.13586	0.20683	-0.08737	-0.21818	-0.29784	-0.03054	-0.22387	-0.11541	-0.17367	0.10102	-0.13962	0.08633	0.21726		
jmbaamyldm	0.29664	0.23919	-0.02309	0.24271	-0.22337	-0.12827	0.54573	0.58762	0.027	0.06611	-0.1832	0.24345	0.24619	-0.16697	0.23496	-0.17553	-0.10734	
jmbaamyldm	0.07123	0.51991	-0.23212	0.47801	-0.38217	0.05526	-0.17172	-0.03823	0.17017	0.17293	0.00019	0.06182	0.50418	-0.23545	0.46144	-0.33758	0.06149	
jmbaamyldm	-0.17798	0.09972	-0.03901	0.04454	-0.16216	0.38734	0.09491	0.16085	-0.02701	-0.20176	-0.13105	-0.20244	0.09828	-0.04017	0.04695	-0.2027	0.32516	
jmbaamyldm	-0.04638	0.2108	0.05472	0.21682	-0.10449	0.10173	0.06301	0.09784	-0.05644	-0.04246	0.03885	-0.01365	0.20282	0.3465	-0.12991	0.12661		
jmbaamyldm	-0.14478	-0.35937	0.11807	-0.31911	0.27769	-0.21019	0.03609	-0.23544	-0.16659	-0.351	0.07822	-0.16904	-0.34454	0.08447	-0.31011	0.32744	-0.18063	
jmbaamyldm	-0.36273	0.02181	-0.26467	0.05252	-0.31505	0.43574	0.16784	-0.1226	0.39558	-0.32201	0.04699	-0.07866	0.07779	-0.07866	0.07779	-0.27899	-0.17927	
jmbaamyldm	0.35102	0.09391	0.06182	0.04028	0.06046	0.13612	-0.05843	0.19358	-0.05705	0.10933	0.32191	0.07198	-0.07221	0.02708	0.04031	0.09129		
jmbaamyldm	0.26997	-0.02498	0.21845	-0.00782	0.04726	0.15393	0.00814	0.03581	-0.2668	-0.1429	-0.52153	0.29713	-0.04422	-0.03235	0.02071	0.17658		
jmbaamyldm	0.17672	0.11166	0.17464	0.1402	-0.09153	-0.07656	-0.11858	-0.04682	0.05758	-0.13974	-0.11446	0.24557	0.09767	0.16661	0.13156	-0.09362	0.04257	
jmbaamyldm	-0.54108	0.07872	-0.24642	0.13054	-0.13893	-0.28105	0.20752	0.02871	0.28623	0.03681	-0.6422	-0.54327	0.11544	-0.02842	0.15507	-0.11247	-0.26463	
jmbaamyldm	0.11621	0.0645	-0.09819	0.01295	0.03921	-0.05308	0.0402	0.22378	0.02357	0.20867	-0.26484	0.06904	0.06035	-0.19844	0.01189	0.04381	-0.14008	
jmbaamyldm	-0.46873	-0.25428	-0.07696	-0.20887	0.05317	-0.1904	0.1419	-0.14308	-0.1639	-0.16291	0.48114	-0.50605	-0.21656	0.08157	0.0716	-0.22869		
jmbaamyldm	-0.11309	-0.06522	0.11542	-0.01337	-0.0299	0.07542	-0.00566	-0.20476	-0.02984	-0.21572	0.23439	-0.05756	0.21294	-0.01285	-0.03797	0.1641		
jmbaamyldm	0.02197	0.19356	-0.00483	0.23221	-0.2462	-0.32284	0.03388	0.24803	-0.00597	-0.11017	-0.19416	0.01709	0.19129	0.03608	0.22604	-0.21361	-0.29798	
jmbaamyldm	0.1159	0.15072	0.00672	0.10111	-0.10996	0.22182	-0.10862	0.08885	-0.01342	0.14847	-0.21237	0.10102	0.14254	-0.01116	0.09596	-0.15692	0.16261	
jmbaamyldm	-0.25698	0.04554	-0.15548	0.07772	-0.23035	-0.09178	0.09109	0.00515	0.14598	-0.30406	0.14959	-0.24392	0.06684	0.07058	0.09308	-0.20427	-0.06632	
jmbaamyldm	-0.07642	-0.14155	0.08392	-0.10107	0.19382	-0.17558	0.01302	-0.15613	-0.04184	-0.12498	0.12358	-0.05705	-0.13521	0.1123	-0.0998	0.22989	-0.10778	
jmbaamyldm	-0.33477	0.11006	-0.24895	0.15125	-0.30678	-0.07612	0.44422	0.23769	0.14271	-0.06451	0.48051	-0.31937	0.12829	0.05463	0.15283	-0.27864	-0.06306	
jmbaamyldm	0.08685	0.17613	-0.06019	0.12947	-0.13047	0.19945	-0.06186	0.13653	0.05187	0.14657	-0.18357	0.0642	0.16824	-0.07742	0.12749	-0.17431	0.1334	
jmbaamyldm	-0.36887	0.14467	-0.26733	0.1928	-0.29133	-0.08228	0.38748	0.24421	0.15936	-0.18419	0.31853	-0.35666	0.1588	0.01326	0.19717	-0.26246	-0.06432	
jmbaamyldm	-0.05405	-0.15498	0.06624	-0.10901	0.13778	-0.2007	0.03154	-0.14276	-0.05278	-0.1511	0.12615	-0.03036	-0.15063	0.0855	-0.10808	0.17788	-0.12871	
jmbaamyldm	-0.30475	0.10999	-0.19872	0.15995	-0.24064	-0.11249	0.25037	0.10141	0.15434	-0.17206	0.38401	-0.29813	0.13097	0.09076	0.16763	-0.23305	-0.0879	
jmbaamyldm	-0.47197	0.03662	-0.23213	0.06766	-0.33151	-0.2311	0.21847	0.12769	0.09255	0.15228	-0.46232	0.06831	-0.07663	0.09973	-0.29613	-0.26712		
jmbaamyldm	-0.02015	-0.14791	-0.02828	-0.11469	-0.19684	-0.20704	0.16366	-0.02619	0.12673	0.19775	-0.39765	-0.02152	-0.11559	-0.06538	-0.10561	-0.2146		
jmbaamyldm	-0.3434	-0.04157	0.23342	-0.04424	0.13282	0.08495	-0.18805	-0.11174	-0.06375	0.30841	-0.45688	-0.38051	-0.0634	0.09367	-0.07172	0.10307	0.12082	
jmba																		

jmbaamzcdm	-0.00342	-0.13706	-0.04289	-0.10487	-0.21779	-0.22469	0.18158	-0.01728	0.14192	0.20536	0.36866	-0.00091	-0.10611	-0.07346	-0.09674	-0.19352	-0.22816
jmbmbzcdm	-0.05222	-0.04527	0.23471	-0.04646	0.1348	0.08617	-0.18758	-0.11736	-0.06229	0.30154	-0.48097	-0.00091	-0.06862	0.09357	-0.09674	-0.19352	-0.22816
jmbmbzdec	-0.33295	-0.16665	0.17636	-0.12599	0.24158	-0.07249	-0.11092	-0.20699	-0.07304	-0.26262	-0.22811	-0.38103	-0.10183	0.24923	-0.13631	0.23306	-0.05635
jmbmbzdec	-0.16405	-0.36537	-0.36537	-0.36537	-0.36537	-0.36537	-0.36537	-0.36537	-0.36537	-0.36537	-0.36537	-0.36537	-0.36537	-0.36537	-0.36537	-0.36537	-0.36537
jmbmbzdec	0.20477	0.4571	-0.07042	0.41072	-0.26827	0.0215	0.3001	0.40194	0.55962	0.26029	-0.18785	-0.10183	0.25102	0.46938	0.41474	-0.25854	0.67607
jmbmbzdec	0.10555	0.44804	0.33364	0.33364	0.33364	0.33364	0.33364	0.33364	0.33364	0.33364	0.33364	0.33364	0.33364	0.33364	0.33364	0.33364	0.33364
jmbmbzdec	0.22386	0.43364	0.08195	0.37778	-0.19472	0.18747	-0.03322	0.15062	0.40101	0.14994	-0.32328	0.27502	0.43821	0.01476	0.38705	-0.19302	0.24528
jmbmbzdec	-0.13849	-0.26874	-0.26874	-0.26874	-0.26874	-0.26874	-0.26874	-0.26874	-0.26874	-0.26874	-0.26874	-0.26874	-0.26874	-0.26874	-0.26874	-0.26874	-0.26874
jmbmbzdec	-0.02081	-0.25609	-0.25609	-0.25609	-0.25609	-0.25609	-0.25609	-0.25609	-0.25609	-0.25609	-0.25609	-0.25609	-0.25609	-0.25609	-0.25609	-0.25609	-0.25609
jmbmbzdec	0.22925	0.37063	0.37063	0.37063	0.37063	0.37063	0.37063	0.37063	0.37063	0.37063	0.37063	0.37063	0.37063	0.37063	0.37063	0.37063	0.37063
jmbmbzdec	0.0638	-0.35741	0.24645	-0.35131	0.37186	0.1259	-0.17153	-0.00333	-0.4019	-0.08494	-0.23813	0.00865	0.2329	-0.38513	0.37367	0.06353	0.03519
jmbmbzdec	-0.18289	0.40524	-0.08007	0.35855	-0.26723	-0.01178	0.29708	0.37333	0.65542	0.26459	-0.15651	0.17766	0.42123	-0.05419	0.36338	-0.25364	0.03385
jmbmbzdec	0.14805	0.40524	-0.08007	0.35855	-0.26723	-0.01178	0.29708	0.37333	0.65542	0.26459	-0.15651	0.17766	0.42123	-0.05419	0.36338	-0.25364	0.03385
jmbmbzdec	0.28449	0.17569	-0.09989	0.17525	0.07576	-0.08252	-0.25866	0.00743	0.26488	0.16885	-0.25862	0.32744	0.15108	-0.04955	0.1621	0.05489	-0.06021
jmbmbzdec	-0.22678	0.00352	-0.04625	0.00542	-0.12867	0.00536	0.88008	0.46323	-0.20748	-0.04838	0.31135	-0.28204	0.0137	-0.01711	0.01081	-0.08707	-0.03047
jmbmbzdec	-0.1469	0.37556	-0.37556	-0.37556	-0.37556	-0.37556	-0.37556	-0.37556	-0.37556	-0.37556	-0.37556	-0.37556	-0.37556	-0.37556	-0.37556	-0.37556	-0.37556
jmbmbzdec	-0.0778	-0.14056	0.09588	-0.1627	0.0398	-0.05367	0.34895	0.26666	-0.29823	0.02717	-0.00118	-0.14368	-0.13572	-0.04491	-0.16811	0.07834	-0.12062
jmbmbzdec	-0.08015	-0.18715	0.11382	-0.21326	0.08632	-0.05172	0.38628	0.27072	-0.31894	0.02645	0.0148	-0.15615	-0.18128	-0.03496	-0.21392	0.13531	-0.12456
jmbmbzdec	-0.17439	-0.17778	-0.04104	-0.20887	0.04567	-0.22697	0.39203	0.3168	-0.24	0.04027	0.1157	-0.24833	-0.17221	-0.1937	-0.20775	0.09834	-0.3127
jmbmbzdec	-0.10731	-0.17593	0.07111	-0.20331	0.06737	-0.09631	0.3829	0.29087	-0.2977	0.03066	0.04308	-0.18085	-0.1701	-0.08599	-0.20378	0.11664	-0.17312
jmbmbzdec	-0.05595	-0.16606	0.0804	-0.19528	0.02492	-0.02833	0.43789	0.28563	-0.33639	0.00725	0.02367	-0.12298	-0.18107	-0.04457	-0.1993	0.06601	-0.09211
jmbmbzdec	-0.10887	-0.07191	0.05828	-0.10984	0.00553	-0.05004	0.37881	0.30813	-0.28339	0.0268	0.01957	-0.18109	-0.06808	-0.06713	-0.11315	0.03901	-0.11037
jmbmbzdec	-0.05983	-0.15865	0.07789	-0.18895	0.02296	-0.03032	0.43416	0.29793	-0.33307	0.00938	0.02299	-0.12574	-0.15377	-0.04749	-0.19294	0.0636	-0.09409
jmbmbzdec	0.10349	0.05987	-0.15146	0.08577	0.02732	-0.08957	-0.07488	0.0101	0.14696	-0.01735	-0.25182	0.08374	0.08613	-0.28391	0.10166	0.07492	-0.05283
jmbmbzdec	-0.11092	-0.1154	0.07441	-0.15583	0.04469	-0.04096	0.41073	0.31113	-0.31132	0.02408	0.03388	-0.17218	-0.1099	-0.08118	-0.15602	0.08787	-0.10627
jmbmbzdec	-0.06803	-0.19701	0.09157	-0.23009	0.06338	-0.02994	0.46367	0.28831	-0.34658	0.00904	0.0438	-0.14247	-0.19035	-0.04131	-0.23082	0.11382	-0.08824
jmbmbzdec	-0.06875	-0.19469	0.07067	-0.23086	0.05498	-0.10063	0.45237	0.3198	-0.3441	0.00711	0.02152	-0.14976	-0.1887	-0.07818	-0.23196	0.10937	-0.17178
jmbmbzdec	-0.07594	-0.16629	0.08701	-0.22298	0.05236	-0.10081	0.44809	0.32068	-0.33831	0.00915	0.02515	-0.15501	-0.18034	-0.0817	-0.22392	0.10574	-0.17182
jmbmbzdec	-0.05098	-0.29236	0.18064	-0.3025	0.14113	0.27268	0.2551	-0.00882	-0.32809	-0.08802	0.04553	-0.09239	-0.27762	0.08218	-0.28847	0.16108	0.21038
jmbmbzdec	0.05672	-0.12399	0.17322	-0.15684	0.12818	-0.05187	-0.01756	0.04578	-0.27133	-0.04255	-0.30313	0.03198	-0.12535	-0.07875	-0.15973	0.12937	-0.10493
jmbmbzdec	0.18825	0.30533	-0.07747	0.30564	-0.14287	0.14588	-0.11276	0.04757	0.34928	0.10009	-0.10372	0.27099	0.287	0.0787	0.16976	0.23471	0.03471
jmbmbzdec	-0.05979	-0.16874	0.09292	-0.21319	0.13109	-0.17566	0.03607	0.03495	-0.29015	-0.03859	-0.12418	-0.11325	-0.18115	-0.14808	-0.21105	0.14764	-0.25289
jmbmbzdec	0.08218	0.18781	-0.08317	0.21181	-0.12469	0.18629	-0.03809	-0.03442	0.28015	0.04437	0.09921	0.14096	0.17879	0.1573	0.20873	0.14468	0.26573
jmbmbzdec	-0.16755	-0.2433	0.16856	-0.24655	0.06155	-0.05947	0.06622	-0.04158	-0.38773	-0.25967	-0.01939	-0.24202	-0.22933	0.00612	-0.2418	0.07847	-0.10683
jmbmbzdec	0.06822	0.1206	-0.11819	0.14596	-0.03973	0.08056	-0.03021	0.27073	-0.07893	-0.01098	0.08928	0.1113	0.03298	0.14074	-0.05007	0.13919	-0.10683
jmbmbzdec	-0.08011	-0.19658	0.16403	-0.21136	0.07288	-0.09303	0.00459	-0.0298	-0.35018	-0.08962	-0.06863	-0.13647	-0.18764	-0.01418	-0.20909	0.08348	-0.15818
jmbmbzdec	0.09778	0.21388	-0.13268	0.22675	-0.04426	0.12191	-0.05444	0.00435	0.32487	0.07617	0.00583	0.15292	0.20719	0.05519	0.22239	0.0569	0.18916
jmbmbzdec	-0.08162	-0.19401	0.1474	-0.2074	0.07734	-0.09813	0.02931	-0.00968	-0.32957	-0.08291	-0.05659	-0.15404	-0.18429	-0.0351	-0.20408	0.08795	-0.15679
jmbmbzdec	0.09857	0.19553	-0.13361	0.20757	-0.06075	0.10708	-0.04154	0.00589	0.32343	0.07555	0.02369	0.15726	0.18399	0.04946	0.20321	0.07167	-0.17522
jmbmbzdec	-0.14194	-0.25752	0.06281	-0.24398	-0.06967	-0.21548	0.11736	-0.03745	-0.35542	-0.00391	0.37973	-0.18122	-0.23185	-0.03413	-0.23	-0.04537	-0.26618
jmbmbzdec	0.35175	0.20447	-0.11679	0.20991	-0.07656	0.14127	-0.0323	0.03473	0.34589	0.22403	-0.03495	0.42387	0.19366	0.00118	0.20501	-0.11685	0.19271
jmbmbzdec	-0.18409	0.01237	-0.01718	-0.01345	-0.10516	-0.1269	0.10271	0.10705	-0.21184	-0.00354	0.09163	-0.21055	0.02735	-0.16659	-0.00675	-0.08864	-0.17118
jmbmbzdec	0.20168	-0.40304	0.23036	-0.44055	0.25588	-0.03524	-0.33077	-0.35633	-0.23351	-0.16299	-0.21842	0.19857	-0.45856	0.24945	0.05456	0.24945	-0.02597
jmbmbzdec	-0.06589	-0.29697	0.18558	-0.318	0.13939	-0.1333	0.10331	-0.00515	-0.42804	-0.09121	-0.01989	-0.12986	-0.28379	-0.02463	-0.30908	0.17658	-0.1979
jmbmbzdec	0.43075	-0.33243	0.26359	-0.3556	0.40551	0.06584	-0.25177	-0.33479	-0.12083	-0.16638	-0.35805	0.39068	-0.31789	0.2146	-0.33384	0.40587	0.06729
jmbmbzdec	-0.12552	-0.24023	0.14543	-0.25251	0.05512	-0.13988	0.09637	-0.00806	-0.37283	-0.09459	0.03553	-0.18026	-0.22471	-0.02724	-0.24608	0.08192	-0.19562
jmbmbzdec	-0.14215	-0.25769	0.06481	-0.2441	-0.06706	-0.2145	0.11624	-0.03803	-0.36018	-0.00626	0.37558	-0.18157	-0.23267	-0.03212	-0.24297	-0.26513	-0.19182
jmbmbzdec	0.34946	0.20328	-0.11732	0.20899	-0.07803	0.14022	-0.03296	0.03347	0.3465	0.22135	-0.03676	0.42087	0.19258	0.00027	0.20418	-0.11524	0.19182
jmbmbzdec	-0.18185	0.0057	-0.01317	-0.01997	-0.10172	-0.12867	0.09691	0.10157	-0.21939	-0.00686	0.08936	-0.20856	0.02028	-0.16275	-0.01358	-0.08661	-0.17315
jmbmbzdec	0.20387	-0.42932	0.23078	-0.43947	0.25528	-0.03524	-0.33115	-0.35573	-0.23306	-0.1621	-0.21979	0.2008	-0.45749	0.3138	-0.45349	0.24905	-0.02579
jmbmbzdec	-0.27277	-0.04531	-0.00869	-0.05796	-0.08486	-0.10734	0.24395	0.14515	-0.23261	-0.01067	0.24211	-0.31786	-0.02118	-0.14171	-0.04316	-0.15848	-0.15848
jmbmbzdec	0.21173	-0.31382	0.16986	-0.34232	0.41605	0.09935	0.21026	0.022	-0.08606	0.02946	-0.08296	0.15485	-0.31847	0.1811	-0.33258	0.47868	0.07803
jmbmbzdec	-0.23715	-0.02519	-0.00823	-0.03423	-0.13786	-0.14671	0.07101	0.03918	-0.2207	-0.06073	0.14206	-0.26198	-0.06668	-0.12257	-0.02773	-0.1313	-0.18335
jmbmbzdec	-0.08406	-0.14647	0.0865	-0.17069	0.04307	-0.07038	0.36701	0.28308	-0.30658	0.03043	0.0104	-0.15287	-0.14217	-0.05848	-0.17403	0.08476	-0.13985
jmbmbzdec	-0.08931	-0.03334	0.05343	-0.06321	-0.00778	-0.05228	0.40032	0.35462	-0.23277	0.07371	0.01092	-0.1526	-0.02532	-0.10583	-0.0625	0.03402	-0.11495
jmbmbzdec	-0.176	-0.18176	-0.00849	-0.20828	0.0505	-0.23037	0.34075	0.28138	-0.26428	0.00779	0.08243	-0.2477	-0.17611	-0.17474	-0.20626	0.09413	-0.31084
jmbmbzdec	-0.1128	-0.04903	0.03505	-0.07851	-0.0109	-0.0902	0.39627	0.3513	-0.23326	0.06047	0.02857	-0.17619	-0.04119	-0.13297	-0.07781	0.03044	-0.15621
jmbmbzdec																	

	jmblaaxyldm	jmbfaaxyldm	jmbbaaxyldm	jmbuaaxyldm	jmbdaaxyldm	jmbtaaxyldm	jmaaxyldm	jmayzdbm	jmbtaamyldm	jmbaamyldm	jmbraamyldm	jmblaamyldm	jmbfaamyldm	jmbbaamyldm	jmbuaamyldm	jmbdaamyldm	jmbtaamyldm
jsfpdbyacc	-0.106	0.25176	-0.02447	0.21242	-0.17931	-0.05619	0.24388	0.33151	-0.0253	0.14626	0.0234	-0.1219	0.26704	-0.19844	0.2169	-0.17458	-0.08912
jsfpdbzacc	-0.10762	0.32644	-0.04627	0.29284	-0.23281	-0.0424	0.23038	0.3451	0.01573	0.15972	0.03757	-0.11777	0.34263	-0.21191	0.26827	-0.23588	-0.06792
jsfpdbrecogn	-0.11579	0.25625	-0.02922	0.2204	-0.18906	-0.063	0.23821	0.32547	-0.02082	0.14175	0.03719	-0.13274	0.2728	-0.20457	0.22735	-0.1855	-0.09515
jfreq	-0.28335	-0.33253	0.10025	0.11273	0.05288	-0.12846	0.11141	-0.15255	-0.34681	-0.1615	0.2534	-0.34516	-0.30357	0.01742	-0.29741	0.07563	-0.18072
mbscontrol	-0.03728	0.17328	-0.13394	0.13569	-0.16731	0.07477	0.17389	0.21663	0.01516	-0.38887	-0.04314	-0.06077	0.17172	0.06595	0.14654	-0.1898	0.09053
mbsboss	-0.16596	0.05715	-0.32612	0.0402	-0.17851	0.10803	0.22119	0.12633	0.20374	-0.04962	0.13458	-0.18796	0.05129	-0.20657	0.0454	-0.18871	0.09989
mbscow	0.04011	0.01241	-0.15427	-0.01487	0.0664	-0.11708	-0.00918	-0.03625	0.12944	0.02724	-0.095	-0.00716	0.01138	-0.14329	-0.03225	-0.01911	-0.10661
mbsatis	-0.00437	-0.02265	-0.06337	-0.04233	0.00008	0.08459	-0.02398	-0.06332	0.01821	-0.10611	-0.00969	-0.08059	-0.03129	0.05356	-0.06354	-0.00413	0.06832
mageb	-0.22243	-0.0704	0.00764	-0.066	-0.00682	-0.22154	-0.24673	-0.31724	0.0384	-0.09046	0.2108	-0.17793	-0.0721	-0.15789	-0.08001	-0.05836	-0.21758
mbsmib	0.04728	-0.19911	-0.05389	-0.1378	0.05476	-0.04832	-0.23492	-0.25481	-0.12016	0.00279	-0.038	0.02839	-0.20046	-0.09445	-0.14638	-0.0005	-0.03751
mbs3	0.26283	0.43832	0.00537	0.40068	-0.18128	-0.07595	-0.15885	0.06857	0.23487	0.259	0.23487	-0.21064	0.27639	0.43147	-0.02584	0.39326	0.01863
mbs4	-0.39539	-0.13518	-0.09297	-0.09262	0.00585	-0.42084	-0.12118	-0.18414	-0.17088	-0.13102	0.34146	-0.37678	-0.12931	-0.08754	-0.10495	0.03388	-0.44527
mbs5	-0.3762	-0.10753	-0.04429	-0.06878	-0.01332	-0.37733	-0.11031	-0.13259	-0.20829	-0.15738	0.26863	-0.38082	-0.11551	-0.02439	-0.08857	0.01711	-0.40332
mbs6	-0.18887	-0.09825	-0.17294	-0.04182	-0.0632	-0.32227	-0.16576	-0.27411	-0.1015	-0.15119	0.26888	-0.15617	-0.10826	-0.05154	-0.05192	-0.0528	-0.32252
mbs7	-0.08795	0.23476	0.02034	0.27647	-0.09501	0.15993	-0.22451	-0.12714	0.07809	-0.03655	0.0244	-0.08845	0.21768	0.1902	0.26939	-0.06071	0.16415
mbs8	0.3445	0.05384	-0.01859	0.06882	-0.07996	-0.15008	-0.23503	-0.06447	0.01561	0.12081	-0.13549	0.30681	0.04458	-0.06838	0.06741	-0.10989	-0.12409

[illegible]

	jmamrdbm	jmplamrdbm	jmbaamrdbm	jmbraamrdbm	jmblaamrdbm	jmbfaamrdbm	jmbbaamrdbm	jmbuaamrdbm	jmbdaamrdbm	jmblaamrdbm	jmaardbm	jmaasagp	jmplaasagp	jmaasymamsp	jmaaslmamsp	jmaasymamsp	jmaasymamsp	jmaasymamsp
jmamrdbm	1.000																	
jmplamrdbm	0.26307	1.000																
jmbaamrdbm	0.22151	0.35129	1.000															
jmbraamrdbm	0.1089	0.0519	0.0801	1.000														
jmblaamrdbm	-0.02854	0.00091	0.20681	-0.646	1.000													
jmbfaamrdbm	0.5849	0.5685	0.26412	0.15048	-0.05669	1.000												
jmbbaamrdbm	-0.27584	-0.2306	-0.0108	-0.04003	0.00157	-0.25712	1.000											
jmbuaamrdbm	0.53877	0.54946	0.18549	0.19758	-0.06468	0.08315	-0.23823	1.000										
jmbdaamrdbm	-0.37966	-0.30908	0.00853	-0.33126	0.16099	-0.6878	0.26968	-0.65814	1.000									
jmbaamrdbm	0.03046	-0.04552	-0.08736	0.16648	0.02895	-0.02142	-0.02234	0.02895	-0.02142	1.000								
jmaardbm	0.00000	0.14143	0.12281	0.18649	-0.1135	0.24953	-0.24025	0.21049	-0.16573	-0.06802	1.000							
jmaasagp	0.11817	0.01093	-0.00938	-0.19605	0.12828	0.0286	0.06219	-0.03471	0.01172	0.04298	0.04298	1.000						
jmplaasagp	0.14658	0.29687	0.05712	-0.41038	0.43688	0.34855	-0.02732	0.32852	-0.17161	0.44683	-0.09536	0.38012	1.000					
jmaasymamsp	0.02419	0.21599	0.14425	0.1209	0.08581	0.37471	-0.19812	0.37673	-0.38163	0.036	0.68216	0.01783	0.02419	1.000				
jmaaslmamsp	0.69695	0.20469	0.12259	0.11992	0.09292	0.35186	-0.19054	0.35939	-0.38249	0.0317	0.87898	0.00707	0.01181	0.00707	1.000			
jmaasymamsp	-0.18588	-0.22939	0.07768	-0.17831	-0.14438	-0.14075	0.14468	-0.0917	0.07712	0.16382	-0.11596	0.12503	-0.06334	-0.23011	-0.22321	1.000		
jmaasymamsp	0.02419	-0.00016	0.10273	-0.14899	0.18537	0.25865	-0.10448	0.20849	-0.15308	0.25211	0.6888	0.25044	0.13162	0.04316	0.04316	-0.16159	1.000	
jmaasymamsp	-0.21603	-0.29477	0.02246	-0.21287	-0.1178	-0.16886	0.13891	-0.13792	0.07208	0.21949	-0.14561	0.16784	-0.06255	-0.21039	-0.2007	-0.2007	-0.09357	1.000
jmaasymamsp	0.57877	0.06308	0.11325	-0.17809	0.26247	0.24759	-0.15117	0.23675	-0.15992	-0.11401	0.53531	-0.16053	0.12133	0.70374	0.70438	-0.22511	0.84328	-0.16754
jmaasymamsp	0.02419	0.19566	0.20305	-0.00357	0.06451	0.50702	-0.25157	0.4609	-0.32995	0.05711	0.02453	0.09901	0.23091	0.7705	0.7705	-0.20941	0.84706	-0.20679
jmaasymamsp	0.15698	-0.0256	-0.18145	-0.13675	-0.2059	0.10043	0.00015	0.04105	-0.20566	0.32491	0.05445	0.43044	0.04646	0.02439	0.02439	0.02035	0.18114	0.17877
jmaasymamsp	0.09843	-0.08998	-0.06248	0.0361	-0.01008	0.20823	0.26368	0.19982	-0.14016	0.13915	0.03409	0.11924	0.21468	0.03784	0.03784	0.01573	0.10233	0.25337
jmaasymamsp	-0.23457	-0.15955	-0.33726	0.0856	-0.16713	-0.34988	0.06979	-0.30913	0.32011	-0.18721	-0.00059	-0.32441	-0.31858	0.05852	0.07468	0.23539	0.00101	0.24727
jmaasymamsp	0.24773	0.1641	-0.12125	0.39753	-0.31078	0.04542	-0.10204	0.07227	-0.29145	-0.18037	0.37714	-0.20186	-0.27592	0.40117	0.41375	-0.09044	0.25729	-0.04369
jmaasymamsp	0.18748	-0.05643	0.12725	-0.56527	0.32344	0.07627	-0.00216	0.02459	0.05793	0.09731	0.00858	0.22054	0.34135	-0.102	-0.11806	-0.1129	0.16977	-0.0634
jmaasymamsp	0.02916	-0.2727	-0.12877	-0.52227	0.29821	-0.03873	0.26737	-0.02827	0.02893	0.17657	-0.05713	0.13068	0.30235	-0.02778	-0.0307	0.11121	0.24975	0.21982
jmaasymamsp	-0.04721	0.07528	-0.13195	-0.11096	0.23452	0.09227	0.15523	0.13667	-0.07265	0.02814	-0.10431	-0.19558	0.48794	0.04646	0.063	0.07796	-0.04664	0.03429
jmaasymamsp	0.03703	0.27181	0.02736	0.66683	-0.54033	0.11178	-0.10523	0.15514	-0.14055	-0.26309	0.19057	-0.28015	-0.43928	0.18942	0.16928	0.02416	-0.10834	-0.01857
jmaasymamsp	0.22121	0.01627	0.22519	-0.27466	0.0717	0.06323	-0.1346	0.00682	0.04329	-0.13012	0.13086	0.07033	-0.06234	-0.04381	-0.06348	-0.22068	0.11084	-0.17116
jmaasymamsp	-0.14093	-0.19296	-0.16672	0.48817	-0.49559	-0.2146	0.06468	-0.19287	0.03707	-0.22057	0.06381	-0.21618	-0.88038	-0.00619	-0.00412	0.12879	0.0074	0.19757
jmaasymamsp	-0.20282	-0.02508	-0.2286	0.24359	-0.05978	-0.06367	0.16367	-0.00777	-0.03903	0.155	-0.11207	-0.05502	0.0838	0.05427	0.07449	0.2129	-0.06741	0.18038
jmaasymamsp	0.24711	0.00259	-0.09827	-0.19431	0.01184	0.18865	0.07459	0.22855	-0.198	-0.3034	0.12405	-0.30421	0.08412	0.05172	0.04781	0.02298	0.13451	0.03583
jmaasymamsp	0.08555	-0.02623	0.14581	-0.2234	0.10212	0.1475	0.02867	0.09207	-0.15185	0.17144	-0.09243	0.32448	0.12992	-0.1448	-0.15898	-0.10834	0.01893	-0.05208
jmaasymamsp	0.00635	0.1361	-0.31937	0.16185	-0.23606	0.06912	0.00779	0.08961	-0.22579	-0.06308	0.04603	-0.09978	-0.04985	0.04689	0.04513	0.32	0.00305	0.31475
jmaasymamsp	-0.15127	-0.03683	-0.11407	0.13314	-0.05771	-0.14091	0.06581	-0.09628	0.22703	-0.11428	-0.01079	-0.27895	-0.07447	0.06489	0.07127	0.14065	-0.05936	0.10063
jmaasymamsp	0.23719	0.1336	-0.07114	0.4913	-0.31291	0.13097	-0.02398	0.151	-0.30046	-0.05932	0.36061	-0.0727	-0.26585	0.37729	0.37624	0.08342	0.23381	0.07741
jmaasymamsp	0.13291	0.04214	0.13739	-0.19324	0.06503	0.17358	-0.03747	0.12358	-0.18977	0.14199	-0.03511	0.13129	0.10856	-0.12147	-0.13401	0.11223	0.02474	-0.07205
jmaasymamsp	0.24516	0.14933	-0.19139	0.33011	-0.34945	0.1625	-0.06478	0.19672	-0.27764	-0.06139	0.33058	-0.06935	-0.12083	0.28301	0.27799	0.19244	0.23277	0.19895
jmaasymamsp	-0.13919	-0.0417	-0.14803	0.13541	-0.03058	-0.15539	0.04152	-0.10386	0.1758	-0.13721	0.0125	-0.31629	-0.06047	0.11389	0.12647	0.12341	-0.02852	0.08244
jmaasymamsp	0.10281	0.14395	-0.18834	0.39372	-0.29059	0.1343	-0.00319	0.18506	-0.25084	-0.08254	0.19134	-0.10391	-0.1895	0.20086	0.19872	0.22387	0.09655	0.23702
jmaasymamsp	0.12951	0.07056	0.13921	-0.49756	-0.45926	0.06479	-0.11632	0.09625	-0.30878	-0.26174	0.21358	-0.21748	-0.43181	0.1723	0.17795	-0.35896	-0.04461	-0.36829
jmaasymamsp	-0.03214	0.12735	0.20484	0.39974	-0.01936	-0.11274	-0.07642	-0.10078	-0.18012	-0.21579	0.08823	-0.22403	-0.25097	0.15816	0.1696	-0.35009	0.10407	-0.3144
jmaasymamsp	-0.11988	-0.0423	0.30691	-0.46553	-0.87796	-0.0616	0.07695	-0.06719	0.13568	0.01585	-0.1844	0.04185	0.41485	-0.01955	-0.00864	-0.23812	0.0314	-0.19318
jmaasymamsp	-0.21371	-0.10379	-0.27214	-0.20804	-0.37132	-0.19639	0.2875	-0.15847	0.26325	-0.11256	-0.06629	-0.20833	-0.14337	-0.14337	0.43641	-0.06119	0.41791	-0.22961
jmaasymamsp	0.3424	0.53933	0.28164	0.17462	-0.08503	0.05829	-0.3202	0.05294	-0.65782	0.05431	0.43182	0.08713	0.30809	0.48224	0.45592	-0.19552	0.41219	-0.22961
jmaasymamsp	0.3424	0.62826	0.27601	-0.23772	0.25968	0.40576	0.00239	0.35745	-0.19211	0.07312	0.2284	0.06146	0.26202	0.25669	-0.23352	0.27692	-0.21445	-0.21445
jmaasymamsp	0.50072	-0.45501	-0.18015	-0.1862	0.06559	0.76524	0.39851	0.76524	0.60893	0.06727	-0.47571	0.01685	-0.12223	-0.43701	-0.42185	0.15663	-0.36508	0.1892
jmaasymamsp	0.1811	0.39118	0.15574	-0.33004	0.2748	0.44613	0.02315	0.39225	-0.20518	0.25503	-0.04173	0.22431	0.48835	0.11622	0.10134	-0.07806	0.11486	-0.06837
jmaasymamsp	0.02427	0.48368	0.26299	0.1535	-0.05156	0.11221	-0.30943	0.05705	-0.54871	0.04731	0.44815	0.08289	0.22853	0.48108	0.43817	-0.16289	0.48738	-0.18113
jmaasymamsp	0.43424	0.71505	0.28805	-0.00514	0.08106	0.8702	-0.16079	0.61415	-0.45515	0.0648	0.2379	0.06633	0.38893	0.3533	0.33894	-0.25667	0.2168	-0.25531
jmaasymamsp	-0.56494	-0.06559	-0.18631	-0.19213	0.09748	-0.30889	0.22023	-0.30148	0.33777	0.07974	-0.55328	0.07974	-0.02726	-0.42878	-0.41728	0.14543	-0.41565	0.20951
jmaasymamsp	0.0732	0.15153	0.00662	-0.3255	0.19513	0.22545	-0.03117	0.18994	-0.11887	0.07384	-0.01134	0.04315	0.30595	-0.08714	-0.09973	0.16733	0.03903	0.16172
jmaasymamsp	0.02427	0.52325	0.27938	0.18999	-0.08994	0.44516	-0.32018	0.37339	-0.6311	0.04416	0.44512	0.07755	0.26825	0.48033	0.45475	-0.18842	0.44859	-0.21739
jmaasymamsp	0.37191	0.02227	0.36418	-0.10064	0.12638	0.57511	-0.10622	0.51495	-0.35812	0.01803	0.19599	0.02466	0.31375	0.27284	0.26266	-0.25773	0.19708	-0.25194
jmaasymamsp	0.13037	0.06681	0.13277	-0.46231	0.06606	0.06606	-0.11784	0.09824	-0.31052	-0.2572	0.21342	-0.21296	-0.43063	0.17063	0.17618	-0.35269	-0.04646	-0.35988

[illegible]

	jmanrdbm	jmplamrdbm	jmbaamrdbm	mbraamrdbm	mblaamrdbm	jmbfaamrdbm	jmbaamrdbm	mbuaamrdbm	jmbdaamrdbm	jmlaamrdbm	jmaardbm	jnameapp	jmplamapp	jmaxymamsp	jmaxsimamsp	jmaxymamsp	jmaxdmamsp	jmaxymamsp
jplpdyacc	0.33572	-0.03897	0.19975	0.01915	-0.11066	0.27102	-0.13647	0.21584	-0.19871	-0.08046	0.19134	-0.00211	-0.14692	0.17456	0.14894	-0.22416	0.36085	-0.19268
jplpdyacc	0.34842	0.00226	0.21116	0.03329	-0.10576	0.34668	-0.15734	0.29531	-0.25923	-0.05887	0.17606	0.01425	-0.10953	0.18882	0.16275	-0.22146	0.36451	-0.18817
jplpdyaccgn	0.32967	-0.03448	0.19411	0.03337	-0.12098	0.27677	-0.14214	0.22431	-0.20984	-0.08638	0.18467	-0.00969	-0.15461	0.17313	0.1481	-0.21985	0.35592	-0.18746
jfreq	-0.15304	-0.36186	-0.1469	0.25738	-0.32468	-0.3006	0.06138	-0.29934	0.04128	-0.17539	-0.00187	-0.16368	-0.59084	-0.00124	0.00403	0.06991	0.0955	0.1239
mbcontrol	0.2159	0.02835	-0.3641	-0.04255	-0.06885	0.17254	0.00183	0.13839	-0.18742	0.0893	0.19984	0.07055	-0.04958	0.18716	0.17635	0.49819	0.05959	0.48301
mbbosa	0.12491	0.22511	-0.10253	0.1404	-0.17295	0.0561	-0.2939	0.04616	-0.18677	0.09331	0.22268	0.13873	-0.05753	0.25157	0.26783	0.11289	0.11531	0.05703
mbcaw	-0.03883	0.17025	0.05269	-0.08718	-0.01072	0.01368	-0.23328	-0.02741	-0.01246	-0.11443	0.0063	-0.07352	-0.15096	0.09253	0.09392	0.09612	0.02383	0.07297
mbcaw	-0.06838	0.04912	-0.07942	0.0067	-0.08118	-0.02559	-0.05393	-0.05389	0.00674	0.07743	-0.02696	0.09645	-0.0844	0.01473	0.0194	0.32205	-0.00817	0.2487
mageb	-0.31068	0.05135	-0.11652	0.21947	-0.18046	-0.06809	-0.13458	-0.0693	-0.06913	-0.21472	-0.21853	-0.23374	-0.25447	-0.27103	-0.26432	0.13027	-0.38586	0.0616
mbmib	-0.25732	-0.12182	-0.026	-0.03193	0.01782	-0.20076	-0.04376	-0.14141	0.00502	-0.04503	-0.21731	-0.05855	-0.02314	-0.05859	-0.03833	-0.08383	-0.25	-0.05572
mbq3	0.07051	0.28798	0.23183	-0.22643	0.27986	0.42954	-0.09453	0.38788	-0.19607	0.01455	-0.12706	0.31586	0.05008	0.0387	-0.02525	-0.03049	-0.06283	-0.06283
mbq4	-0.17534	-0.17549	-0.11657	0.35208	-0.38429	-0.12592	-0.07515	-0.09028	0.0273	-0.44351	-0.04405	-0.45056	-0.46207	-0.22032	-0.21809	0.03123	-0.2361	0.02662
mbq5	-0.12564	-0.20859	-0.14448	0.2789	-0.38163	-0.11124	-0.00051	-0.07689	0.01825	-0.40196	-0.02875	-0.41121	-0.3954	-0.17378	-0.17149	0.04135	-0.1843	0.01759
mbq6	-0.26634	-0.09157	-0.17278	0.27695	-0.15513	-0.10377	-0.09066	-0.04212	-0.05939	-0.32459	-0.14779	-0.37707	-0.353	-0.07524	-0.06058	0.08144	-0.2809	0.04045
mbq7	-0.1214	0.04734	-0.05204	0.02131	-0.07575	0.22093	0.1791	0.27025	-0.05791	0.1715	-0.25465	0.13272	0.06514	-0.11265	-0.11731	0.19069	-0.18561	0.15667
mbq8	-0.06606	0.02644	0.1149	-0.14287	0.30028	0.04513	-0.02918	0.06618	-0.0937	-0.12836	-0.17717	-0.16607	0.15736	0.00594	0.0173	-0.2107	-0.12005	-0.25241

	jnamyzdmamp	jnamrmanp	jnnrlatp	jnpnrlatp	jnnrlatp	jnpnrlatp	jnmsaglv	jnpnmsaglv	jnmsagev	jnpnmsagev	jnmsagacc	jnpnmsagacc	jnmsagdec	jnpnmsagdec	jnnrlatv	jnpnrlatv	jnnrlatv	jnpnrlatv	jnnrlatacc	jnpnrlatacc	jnnrlatdec	jnpnrlatdec
jnduration																						
jndurationne																						
jsduration																						
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jduration																						
jnnmaxsma																						
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jmsxyma																						
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jmbtaamxysm																						
jmaaxysm																						
jnnmxsm																						
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	jnmmbzao	jnmpmbzao	jnmmbzdc	jnmpmbzdc	jnmamoracong	jnplambracong	jnrWL	jmlJ	jnbybyveides	jasmassa	jalditz	jaldafz	jaldafyz	jalexim	jaleysim	jalexym	jalexdm	jaleydm	jalexymd	jefyzdm	jstrdm	jlsagg	jlsaglv	jlsagev
jnmmbzao																								
jnmmbzdc																								
jnmbyaac																								
jnmbybyaac																								
jnmbydc																								
jnmbydeides																								
jnmmbzao	1.000																							
jnmmbzdc	0.67138	1.000																						
jnmmbzdc	-0.00683	-0.50683	1.000																					
jnmmbzdc	-0.35551	-0.58491	0.34901	1.000																				
jnmamoracong	0.006355	0.66355	0.16122	-0.34268	1.000																			
jnplambracong	0.39215	-0.19901	-0.18901	-0.26754	0.39896	1.000																		
jnrWL	0.10516	0.25893	-0.29637	-0.23435	0.09759	0.15551	1.000																	
jmlJ	0.12345	-0.14945	0.07965	0.29944	0.16021	-0.06806	0.00000	1.000																
jnbybyveides	0.00000	0.00000	-0.32999	-0.00000	0.53142	0.12224	0.14468	0.00000	1.000															
jasmassa	-0.03466	-0.2429	0.204	0.20274	0.02832	-0.06654	0.89226	-0.01216	0.00000	1.000														
jalditz	-0.08103	-0.26566	0.26178	0.2161	-0.01235	-0.07705	-0.6158	-0.04693	0.00000	0.00000	1.000													
jaldafz	-0.08425	-0.25701	0.19645	0.20077	0.00327	-0.09834	-0.52364	0.6487	-0.02041	0.00000	0.00000	1.000												
jaldafyz	-0.07129	-0.26469	0.23408	0.21322	0.00498	-0.80407	-0.00000	-0.03032	0.00000	0.00000	0.00000	0.00000	1.000											
jalexim	-0.06776	-0.25361	0.24924	0.2413	-0.06077	-0.69583	0.78318	0.8941	-0.03204	0.00000	0.00000	0.00000	0.00000	1.000										
jaleysim	0.01417	-0.21761	0.15516	0.17618	0.08779	-0.10535	-0.84286	0.71853	0.03615	0.00000	0.00000	0.00000	0.00000	0.00000	1.000									
jalexym	-0.06117	-0.25071	0.24182	0.23645	0.00478	-0.86394	-0.89253	0.78318	-0.0263	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	1.000								
jalexdm	0.07869	0.20877	0.08851	-0.02231	0.08934	0.35161	0.17167	-0.28081	0.15871	-0.0826	-0.0547	-0.10684	-0.10466	-0.12264	-0.1449	-0.1249	1.000							
jaleydm	-0.02382	-0.23847	0.20896	0.18659	0.05104	-0.1104	-0.65823	0.78318	0.00605	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	1.000						
jalexymd	-0.09524	-0.26882	0.29187	0.2417	-0.02818	-	-0.69922	0.79491	-0.05323	0.98521	0.87902	0.89861	0.87565	0.99471	0.96365	0.99431	-0.13277	0.97687	1.000					
jefyzdm	-0.09637	-0.25824	0.28261	0.23937	-0.02592	-0.06961	-0.68159	0.78332	-0.05141	0.96162	0.87394	0.92881	0.97893	0.98655	0.98419	0.98895	-0.10406	0.87613	0.98077	1.000				
jstrdm	-0.08864	-0.26568	0.27355	0.23538	-0.01869	-0.07446	-0.68125	0.78164	-0.04444	0.96367	0.87513	0.93284	0.98144	0.98867	0.98828	0.98756	-0.10979	0.88026	0.98073	0.98977	1.000			
jlsagg	-0.21191	-0.36707	0.40772	0.26323	-0.1767	-0.13414	-0.60335	0.69742	-0.1821	0.78037	0.78903	0.8404	0.76759	0.82965	0.77614	0.82663	-0.15568	0.79281	0.83117	0.78924	0.977047	1.000		
jlsaglv	-0.09773	-0.24245	0.20838	0.13502	-0.04602	-0.12848	-0.41741	0.31456	-0.10021	0.82908	0.79959	0.77298	0.80222	0.78564	0.82127	0.77184	0.05077	0.79798	-0.74181	0.76958	0.77413	0.58948	1.000	
jlsagev	0.21125	0.42231	-0.38121	-0.20484	0.17124	0.25192	0.73085	-0.61369	0.20708	-0.86617	-0.87155	-0.83905	-0.88163	-0.86569	-0.86915	-0.86768	0.09164	-0.87608	-0.86683	-0.86568	-0.86965	-0.80905	-0.77071	
jasmagacc	-0.12816	-0.30077	0.25174	0.12812	-0.07275	-0.18457	-0.50411	0.42167	-0.12575	0.87871	0.86519	0.84352	0.88164	0.82593	0.88227	0.83608	-0.02011	0.86886	0.81769	0.84682	0.85246	0.63722	0.9495	
jasmagdec	0.12609	0.30024	-0.24572	-0.10807	0.06862	0.18834	0.49814	-0.41859	0.12095	-0.87771	-0.86434	-0.85012	-0.88273	-0.82529	-0.88093	-0.83172	0.02504	-0.86819	-0.81461	-0.84419	-0.85018	-0.63153	-0.93684	
jlsatrp	-0.18053	-0.38756	0.3312	0.15178	-0.1612	-0.224	-0.72327	0.58458	-0.19098	0.84683	0.84186	0.75877	0.8354	0.84314	0.83179	0.84349	-0.09547	0.82874	0.83373	0.83038	0.81007	0.78921	0.80976	
jlsatrv	0.0628	0.27478	-0.19682	-0.13152	0.00044	0.18623	0.61134	-0.51316	0.0634	-0.83377	-0.81859	-0.75726	-0.82492	-0.81752	-0.82919	0.09645	-0.85133	-0.80548	-0.80344	-0.81005	-0.73334	-0.85415	0.85903	
jlsatrv	-0.14074	-0.3538	0.27816	0.15816	-0.10324	-0.21849	-0.64619	0.50279	-0.15427	-0.88052	-0.86503	-0.78911	-0.86505	-0.8553	-0.87656	0.05861	-0.0391	0.86486	0.83944	0.84544	0.84996	0.75538	0.9236	
jlsatrv	-0.14579	-0.33576	-0.28026	-0.13626	0.10319	0.18184	-0.67714	-0.55247	0.14693	-0.90221	-0.88931	-0.83855	-0.89569	-0.88465	-0.89108	-0.88982	0.06718	-0.88197	-0.86994	-0.87833	-0.87929	-0.77849	-0.89976	
jlsatrac	-0.12393	-0.34465	0.27876	0.15491	-0.09308	-0.2006	-0.65169	-0.52107	-0.1415	0.8808	0.87767	0.81102	0.87948	0.86535	0.88357	0.86843	-0.03948	0.87384	0.85128	0.85883	0.86225	0.78603	0.91878	
jlsatrac	0.12892	0.33336	-0.27529	-0.13637	0.08876	0.1899	0.68537	-0.53318	0.13581	-0.8947	-0.88164	-0.82134	-0.89532	-0.87267	-0.86865	-0.87548	0.04356	-0.87769	-0.8588	-0.86562	-0.86888	-0.78855	-0.90679	
jlsatrv	-0.15278	-0.36487	0.28178	0.05377	-0.12823	-0.27533	-0.73672	0.63759	-0.16991	0.71869	0.72337	0.72772	0.74077	0.75596	0.73108	0.75905	-0.26904	0.73731	0.7573	0.7399	0.7428	0.68021	0.53515	
jlsatrv	0.15001	0.38686	-0.25882	-0.1991	-0.11291	0.24635	0.36668	-0.54626	0.15339	-0.82739	-0.82356	-0.76217	-0.82141	-0.79672	-0.82155	-0.79988	0.00895	-0.81915	-0.78277	-0.80405	-0.80711	-0.79547	0.87184	
jlsatrv	0.07177	-0.20473	0.06675	0.01136	0.11991	-0.17025	-0.68212	0.58762	0.05531	0.88219	0.8367	0.80038	0.85262	0.85164	0.90116	0.85759	-0.13222	0.87992	0.83108	0.83309	0.84074	0.75146	0.8331	
jlsatrv	-0.51621	-0.23434	0.2106	0.00395	-0.54931	-0.21213	0.42741	-0.43959	-0.55986	-0.43185	-0.40606	-0.36547	-0.41828	-0.42207	-0.47467	-0.42703	-0.27786	-0.4562	-0.40812	-0.37924	-0.38918	-0.42405	-0.62031	
jlsatrv	-0.22201	-0.40556	0.39785	0.17688	-0.18054	-0.23217	-0.68799	0.59105	-0.21728	0.90969	0.91198	0.84513	0.91195	0.9052	0.90709	0.9071	0.07678	0.91382	0.90703	0.90983	0.91119	0.9084	0.86652	
jlsatrv	-0.35402	0.0161	0.53919	-0.12448	-0.43268	0.11332	0.24479	-0.37796	-0.33547	-0.33058	-0.28809	-0.35369	-0.32952	-0.30371	-0.36852	-0.31008	0.24414	-0.33033	-0.27233	-0.2667	-0.27821	-0.18687	0.2364	
jlsatrv	-0.16224	-0.35377	0.33358	0.14307	-0.12457	-0.20453	-0.73986	0.81613	-0.16612	0.91126	0.90808	0.83396	0.90693	0.90874	0.91408	0.91184	-0.08328	0.91202	0.90289	0.90014	0.90324	0.82822	0.84986	
jlsatrv	-0.15319	-0.36842	0.2829	0.05818	-0.1299	-0.28105	-0.73875	0.63945	-0.17121	0.72191	0.72635	0.72885	0.74345	0.75046	0.73488	0.75803	-0.26958	0.74299	0.76131	0.74722	0.74568	0.75568	0.75402	
jlsatrv	0.14845	0.36854	-0.25706	-0.19755	0.11035	0.24737	0.68712	-0.54779	0.15226	-0.83019	-0.82813	-0.76337	-0.82391	-0.7993	-0.84346	-0.80249	0.01155	-0.82175	-0.79515	-0.80068	-0.80918	-0.88343	-0.59252	
jlsatrv	0.0645	-0.21241	0.07003	0.01318	0.11237	-0.17821	-0.87975	0.58442	0.04687	0.66225	0.63673	0.6009	0.65588	0.61827	0.69086	0.85722	-0.13739	0.81795	0.83081	0.83314	0.84074	0.74893	0.82327	
jlsatrv	-0.5154	-0.23278	0.21014	0.00346	-0.54665	-0.21058	0.4287	-0.44418	-0.53789	-0.43343	-0.40776	-0.3672	-0.42002	-0.42362	-0.47842	-0.42878	-0.12759	-0.45808	-0.40997	-0.38094	-0.3909	-0.42623	-0.31851	
jlsatrv	0.05283	-0.22026	0.17346	0.04343	0.09221	-0.16653	0.07945	-0.20394	0.04735	-0.40528	-0.31175	-0.30029	-0.33788	-0.35833	-0.37657	-0.37674	-0.12387	-0.40688	-0.37638	-0.36343	-0.36823	-0.36343	-0.36343	
jlsatrv	-0.31671	-0.03933	0.41353	0.12927	-0.32891	0.08875	0.32332	-0.16421	-0.24268	-0.40528	-0.31175	-0.30029	-0.33788	-0.35833	-0.37657	-0.37674	-0.12387	-0.40688	-0.37638	-0.36343	-0.36823	-0.36343	-0.36343	
jlsatrv	0.04322	-0.21182	0.09878	0.01876	0.07891	-0.17239	0.07935	-0.60352	0.01818	-0.40528	-0.31175	-0.30029	-0.33788	-0.35833	-0.37657	-0.37674	-0.12387	-0.40688	-0.37638	-0.36343	-0.36823	-0.36343	-0.36343	
jlsatrv	-0.04444	-0.25236	0.20556	0.20129	0.02537	-0.07858	-0.59673	0.69755	-0.01515	-0.40528	-0.31175	-0.30029	-0.33788	-0.35833	-0.37657	-0.37674	-0.12387	-0.40688	-0.37638	-0.36343	-0.36823	-0.36343	-0.36343	
jlsatrv	0.06999	-0.16105	0.14169	0.14678	0.14168	-0.02413	-0.58475	0.69491	0.10436	-0.40528	-0.31175	-0.3002												

	jmmbzacc	jmptbzacc	jmmbzdec	jmptbzdec	jmambracong	jmptambracong	jmRWL	jmLJ	jmbyvelides	jsfmasa	jsdftr	jsfadtr	jsfadyz	jsfaxelm	jsfayelm	jsfaxytm	jsfaxdm	jsfaydm	jsfazydm	jsfyzdm	jsfrdbm	jsfagp	jsfaglv	jsfagev
jslpdoyacc	0.32587	0.05262	-0.07761	-0.05486	0.3855	0.05064	-0.54788	0.55126	0.32679	0.65521	0.82321	0.82727	0.82887	0.81444	0.80678	0.82224	0.01022	0.85017	0.81114	0.79088	0.81988	0.65138	0.81847	0.59742
jslpdbzacc	0.39784	0.09053	-0.14457	-0.07297	0.45002	0.06699	-0.53106	0.53068	0.39077	0.81073	0.77271	0.68493	0.77799	0.76885	0.84478	0.77888	0.0324	0.81322	0.74104	0.73857	0.74786	0.61873	0.78004	-0.71594
jslpdbzaccgn	0.33228	0.05181	-0.08077	-0.0564	0.38893	0.05003	-0.55684	0.55371	0.33183	0.85043	0.81795	0.73584	0.80349	0.81032	0.89129	0.81787	0.01708	0.8543	0.70658	0.70658	0.70658	0.65252	0.80318	-0.71129
jsfreq	-0.24313	-0.40724	0.43312	0.24792	-0.23698	-0.23511	0.06198	0.01133	0.68346	0.69477	0.63924	0.89031	0.84226	0.88828	0.82584	-0.10684	-0.04991	-0.06279	-0.05558	-0.05663	-0.08195	-0.12803	0.0902	
mbcontrol	0.13127	0.12171	-0.13339	-0.14592	0.1303	0.01322	0.06198	0.11222	0.16808	-0.12067	-0.11105	-0.10756	-0.11772	-0.07284	-0.06344	-0.07233	-0.15312	-0.18624	-0.15913	-0.1643	-0.18486	-0.09557	-0.31379	0.12378
mbabose	0.04221	0.04998	-0.14878	0.07177	-0.00889	-0.04384	0.06911	-0.24989	-0.22377	-0.13177	-0.20484	-0.18195	-0.21377	-0.18401	-0.16704	-0.16704	-0.08545	-0.11032	-0.06946	-0.06859	-0.201	-0.08091	-0.02668	
mbacow	-0.01441	0.09657	0.02328	-0.13467	-0.0151	0.04175	0.06829	-0.09396	-0.02975	-0.14537	-0.13832	-0.01506	-0.11128	-0.11968	-0.0867	-0.11706	-0.1009	-0.08545	-0.11032	-0.06946	-0.06859	-0.201	-0.08091	-0.02668
mbasls	-0.0461	0.00048	0.02082	-0.10532	-0.05849	0.02934	0.1383	-0.18542	-0.05667	-0.2584	-0.23587	-0.2356	-0.2484	-0.22904	-0.25548	-0.23136	0.04223	-0.23628	-0.2108	-0.21215	-0.21676	-0.17396	-0.27404	0.14677
magelb	-0.06096	-0.082	0.00197	-0.06923	-0.08999	-0.09848	0.05039	-0.17848	-0.10644	-0.21408	-0.21102	-0.08159	-0.17054	-0.20073	-0.17904	-0.19917	-0.18589	-0.17867	-0.1927	-0.18784	-0.18287	-0.10738	-0.15525	-0.04901
mbmib	-0.21816	-0.17999	-0.02046	-0.03707	-0.23542	-0.18031	0.05173	-0.09544	-0.25171	-0.11619	-0.12901	-0.03858	-0.11054	-0.11042	-0.12301	-0.11173	-0.28837	-0.1375	-0.12762	-0.11475	-0.11487	-0.15873	-0.10792	0.09188
mbq3	0.33814	0.34005	-0.29243	-0.21133	0.297	0.21126	0.22459	-0.28923	0.30487	-0.32197	-0.3493	-0.39393	-0.38182	-0.32727	-0.26059	-0.32298	0.17355	-0.28683	-0.3428	-0.33524	-0.33308	-0.33274	-0.1144	0.347
mbq4	-0.08399	-0.23433	0.05932	0.15109	-0.08456	-0.18154	-0.12951	0.09034	-0.08677	0.12053	0.11275	0.23082	0.15462	0.11882	0.14134	0.12062	-0.15063	0.1282	0.11438	0.13103	0.13518	0.06405	0.0179	-0.25884
mbq5	-0.05868	-0.27546	0.02252	0.19375	-0.06006	-0.20399	-0.06547	0.08492	-0.08994	0.16986	0.15793	0.22253	0.18393	0.13464	0.15119	0.13636	-0.17708	0.1345	0.12545	0.13902	0.14148	0.04615	0.06081	-0.24217
mbq6	-0.07823	-0.19706	-0.0184	0.01732	-0.11909	-0.21414	-0.10044	0.08656	-0.14286	-0.03006	-0.03649	0.01193	-0.01514	-0.01417	-0.01866	-0.01416	-0.3688	-0.02919	-0.02095	-0.04118	-0.03735	0.00735	-0.14444	-0.12156
mbq7	0.1982	0.05503	-0.24873	-0.07535	0.14663	-0.02124	0.05524	-0.09228	0.13545	-0.13879	-0.16138	-0.29829	-0.20342	-0.16527	-0.18328	-0.16611	-0.13315	-0.17578	-0.18553	-0.23243	-0.23174	-0.01527	-0.18129	0.18375
mbq8	0.01638	0.04411	-0.18031	-0.12593	0.02054	0.08246	0.18883	-0.13585	0.01059	-0.03199	-0.07008	-0.04981	-0.06272	-0.07856	-0.06564	-0.07772	-0.07708	-0.10322	-0.11332	-0.09445	-0.09466	-0.17361	0.02901	0.14404

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	ispdxaxm	ispdxaym	ispdxayxm	ispdxaxm	ispdxaym	ispdxayxm	ispdpyzdm	isfdrdbm	ispdsagg	ispdsavg	ispdsaga	ispdtpat	ispdttv	ispdtdat	ispdbxam	ispdbvyl	ispdbzvl	ispdborvl	ispdbxacc	ispdbvacc	ispdbzacc	ispdbaccgm	freq	mcount
ispdbyacc	0.84327	0.89399	0.84774	0.89447	0.91387	0.89837	0.89898	0.90302	0.79535	0.84998	0.84691	0.845	0.8439	0.65441	0.78098	0.99934	0.97107	0.99121	0.78183	1.000				
ispdbyacc	0.79855	0.85208	0.80309	0.85868	0.87544	0.86274	0.86206	0.86815	0.75852	0.80948	0.80438	0.80483	0.80051	0.81898	0.73755	0.99571	0.95487	0.98024	0.73841	0.99376	1.000			
ispdbyaccgm	0.83661	0.88458	0.84059	0.88885	0.90533	0.89248	0.89339	0.89741	0.7913	0.84748	0.8427	0.84385	0.84148	0.85189	0.78594	0.99903	0.97218	0.99184	0.78875	0.99938	0.99558	1.000		
ifreq	0.8613	0.84198	0.8597	0.83588	0.85092	0.83047	0.83119	0.82682	0.71361	0.72038	0.8116	0.73838	0.68291	0.6726	0.82176	0.55355	0.68977	0.843	0.81952	0.56451	0.53569	0.57504	1.000	
mcount	-0.0581	-0.09527	-0.05744	-0.0441	-0.07751	-0.04509	-0.04952	-0.05039	-0.11434	-0.11659	-0.12365	-0.08845	-0.10553	-0.10978	-0.13893	-0.10428	-0.10907	-0.11085	-0.14062	-0.11092	-0.09719	-0.11177	-0.08813	1.000
mbsbss	-0.211	-0.24562	-0.21209	-0.21591	-0.23325	-0.21715	-0.21242	-0.21337	-0.19348	-0.23759	-0.29758	-0.28743	-0.25765	-0.26005	-0.17933	-0.23285	-0.24967	-0.2412	-0.17995	-0.23694	-0.21533	-0.22878	-0.0291	0.16986
mbscow	-0.12761	-0.08773	-0.12568	-0.12318	-0.08985	-0.12193	-0.09322	-0.09134	-0.18239	-0.0575	-0.02734	-0.12056	-0.11747	-0.10334	-0.06535	-0.09632	-0.1045	-0.09999	-0.06504	-0.09583	-0.08696	-0.09021	-0.05578	0.23864
mbsatls	-0.22615	-0.25953	-0.22805	-0.2414	-0.25874	-0.2462	-0.2492	-0.20218	-0.21314	-0.23379	-0.26768	-0.21528	-0.20952	-0.23336	-0.09631	-0.267735	-0.28569	-0.23256	-0.29534	-0.28008	-0.29007	-0.18922	-0.36951	
mageb	-0.25588	-0.23568	-0.25397	-0.25772	-0.23021	-0.25505	-0.24355	-0.23859	-0.18107	-0.10946	-0.10697	-0.14375	-0.15834	-0.15253	-0.01229	-0.14175	-0.12931	-0.13322	-0.01131	-0.14161	-0.13684	-0.13168	-0.04921	-0.08094
mmbib	-0.12517	-0.14585	-0.12726	-0.17161	-0.17061	-0.16081	-0.16049	-0.18731	-0.11896	-0.09143	-0.09662	-0.09966	-0.10606	-0.11721	-0.21669	-0.19652	-0.20575	-0.01821	-0.20808	-0.21347	-0.20418	-0.0615	-0.04275	
mbq3	-0.28068	-0.21915	-0.28722	-0.21444	-0.19492	-0.21145	-0.2165	-0.21462	-0.28701	-0.24419	-0.22772	-0.22924	-0.21853	-0.22281	-0.38484	-0.03341	-0.12602	-0.09078	-0.38845	-0.04893	-0.05352	-0.31868	0.05597	
mbq4	0.06516	0.06064	0.06715	0.03041	0.0703	0.03318	0.05119	0.05585	0.02516	0.06417	0.11681	0.09131	0.06383	0.06716	0.23516	0.04737	0.03668	0.07246	0.23666	0.05665	0.03615	0.05216	0.25717	-0.18399
mbq5	0.09965	0.10446	0.10056	0.06631	0.08391	0.06763	0.08039	0.0829	0.04013	0.12581	0.13738	0.13111	0.09678	0.09838	0.23237	0.05428	0.09074	0.07852	0.23427	0.06397	0.04666	0.06833	0.2114	-0.19455
mbq6	-0.08687	-0.10778	-0.08605	-0.10303	-0.12235	-0.12859	-0.13056	-0.1269	-0.09651	-0.05222	-0.08009	-0.03486	-0.06638	-0.0746	-0.09519	-0.10955	-0.06919	-0.08687	-0.09642	-0.10106	-0.10687	-0.09543	0.18271	-0.06352
mbq7	-0.16448	-0.16031	-0.16514	-0.1577	-0.14648	-0.15599	-0.17848	-0.17941	-0.07247	-0.15811	-0.18127	-0.15004	-0.14538	-0.14157	-0.22243	-0.08426	-0.13211	-0.11424	-0.22353	-0.08914	-0.06284	-0.09101	-0.08241	0.10134
mbq8	-0.04776	-0.03615	-0.04852	-0.05262	-0.05568	-0.05822	-0.04881	-0.04846	-0.10679	-0.05391	-0.01492	-0.00041	0.00544	-0.00313	-0.0193	0.00011	-0.02986	-0.01647	-0.01935	0.00026	-0.00035	-0.00226	-0.08426	-0.10730

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	mbstoss	mbscow	mbsatls	mageb	mbmb	mbq3	mbq4	mbq5	mbq6	mbq7	mbq8
jmpmbxaacc											
jnmmbxdec											
jmpmbxdec											
jnmmbyaacc											
jmpmbyaacc											
jnmmbxdec											
jmpmbxdec											
jmmbzacc											
jmpmbzaacc											
jmmbzdec											
jmpmbzdec											
jmaembracong											
jmpmaembracong											
jmlRVL											
jmlJ											
jmblyveides											
jsfsmasa											
jsdfz											
jsfaclhy											
jsfadyf											
jsfaasim											
jsdayim											
jsfazyism											
jsfaaxdm											
jsfaydm											
jsfazyidm											
jsfyzdbm											
jsfirdm											
jsfaagp											
jsfaagfv											
jsfaagev											
jsfaagacc											
jsfaagdec											
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jsfbxdec											
jsfbyaacc											
jsfbxdec											
jsfbzacc											
jsfbzdec											
jsfbracong											
jsfpdasm											
jsfpdadzf											
jsfpdadyf											
jsfpdadyzf											
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jsfpdsagg											
jsfpdsagg											
jsfpdsagg											
jsfpdialp											
jsfpdialp											
jsfpdialp											
jsfpdbxvel											
jsfpdbxvel											
jsfpdbxvel											
jsfpdbxvel											
jsfpdbxacc											

	mbcbosa	mbcsw	mbcsta	mageb	mbmib	mbq3	mbq4	mbq5	mbq6	mbq7	mbq8
jpdpdyacc											
jpdpdzacc											
jpdpdraccgn											
jlreq											
mb-control											
mbcbosa	1.000										
mbcsw	0.34203	1.000									
mbcsta	0.38794	0.53278	1.000								
mageb	0.20532	0.38608	0.20349	1.000							
mbmib	-0.00304	0.06763	-0.16434	-0.16725	1.000						
mbq3	-0.01224	0.17766	0.0463	0.06474	-0.20499	1.000					
mbq4	-0.06965	0.02914	0.03598	0.58751	-0.06976	-0.25934	1.000				
mbq5	-0.08873	-0.04233	0.05313	0.53805	-0.15072	-0.23197	0.6870538	1.000			
mbq6	0.16653	0.03686	0.06712	0.48704	0.20278	-0.17103	0.69691	0.68376	1.000		
mbq7	-0.08053	-0.35338	-0.07015	-0.16427	0.07872	0.08381	-0.00687	0.05972	0.15073	1.000	
mbq8	-0.20862	-0.08993	-0.28023	-0.13233	0.45943	0.253	-0.05022	-0.02041	0.10328	0.03587	1.000

APPENDIX A-4

Variable Glossary

1993 NIOSH Lifting Index (LI) – Calculated as per the Applications Manual for the Revised NIOSH Lifting Equation (1994).

1993 NIOSH Recommended Weight Limit (RWL) – An estimate of the NIOSH RWL in kilograms. RWL was internally calculated for the start and the end of each lift or lower exertion and the smallest RWL is reported. RWLs were calculated using the following data sources: Horizontal Multiplier - Start or End XY Moment ARM; Vertical Multiplier – Start or End Box Height; Distance Multiplier – Absolute value of Start Box Height - End Box Height; Asymmetric Multiplier – Start or End Asymmetry; Frequency Multiplier – Average number of lifting or lowering exertions per minute over the observation period; Coupling Multiplier – Fair. Multiplier values and the RWL were then determined using the equations found in then Applications Manual for the Revised NIOSH Lifting Equation (1994).

Absolute Average Resultant Dynamic Moment – The average of the absolute value of the dot product of the XYZ moment arm vector and the instantaneous YZ force vector over the duration of the exertion in Newton-meters.

Absolute Average XY*Lift Dynamic Lift Moment – The average of the absolute values of the resultant of the X and Y moment arms times the instantaneous Z force on the hands over the duration of the exertion in Newton-meters.

Absolute Average XY*Lift Static Moment – The average of the absolute values of the resultant of the X and Y moment arms times the instantaneous Box Weight over the duration of the exertion in Newton-meters.

Absolute Maximum Box Resultant Acceleration Without Gravity – The maximum of the absolute value of the resultant of the X, Y and Z acceleration vectors measured by the handles with the acceleration due to gravity removed over the duration of the entire exertion. Units are meters per second per second.

Absolute Maximum Box Resultant Velocity – The maximum of the absolute value of the resultant of the X, Y and Z velocity vectors measured by the handles with the acceleration due to gravity removed over the duration of the entire exertion. Velocity is calculated as the derivative of the acceleration measured at the handles. Units are meters per second.

Absolute Maximum Dynamic Y Force – The maximum absolute value of the Z force on the hands in Newtons over the duration of the entire exertion.

Absolute Maximum Dynamic YZ Force – The maximum absolute value of the resultant Y and Z forces on the hands in Newtons over the duration of the entire exertion.

Absolute Maximum Resultant Dynamic Moment – The maximum of the absolute value of the dot product of the XYZ moment arm vector and the instantaneous YZ force vector over the duration of the exertion in Newton-meters.

Absolute Resultant Moment at Absolute Maximum Sagittal Trunk Angle – The Absolute Resultant Moment in Newton-meters at the time of the occurrence of the maximum value of the absolute sagittal trunk angle.

Absolute Maximum Sagittal Trunk Angle – The maximum of the absolute value of the sagittal trunk angle over the duration of the entire exertion. Trunk angle is expressed relative to an upright standard condition. Units are degrees.

Absolute Maximum X-axis Dynamic Lift Moment – The maximum of the absolute value of the Z force times the Y moment arm over the duration of the entire exertion. Units are Newton meters.

Absolute X-axis Dynamic Lift Moment at Absolute Maximum Sagittal Trunk Angle – The absolute value of the X-axis Dynamic Lift Moment in Newton-meters at the time of the occurrence of the Absolute Maximum Sagittal Trunk Angle.

Absolute Maximum X-axis Static Lift Moment – The maximum of the absolute value of the instantaneous Box Weight times the Y moment arm over the duration of the entire exertion. Units are Newton meters.

Absolute X-axis Static Lift Moment at Absolute Maximum Sagittal Trunk Angle – The Absolute X-axis Static Lift Moment in Newton-meters at the time of the occurrence of the maximum value of the absolute sagittal trunk angle.

Absolute Maximum XY*Lift Dynamic Moment – The maximum of the absolute value of the Z force times the XY moment arm over the duration of the entire exertion. Units are Newton meters.

Absolute Maximum XY*Lift Static Moment – The maximum of the absolute value of the instantaneous Box Weight times the XY moment arm over the duration of the entire exertion. Units are Newton meters.

Absolute XY*Lift Static Moment at Absolute Maximum Sagittal Trunk Angle – The Absolute XY*Lift Static Moment in Newton-meters at the time of the occurrence of the maximum value of the absolute sagittal trunk angle.

Absolute Maximum Total Dynamic Sagittal Moment – The maximum of the absolute value of the Z force times the Y moment arm plus the Y force times the Z moment arm over the duration of the entire exertion. Units are Newton meters.

Absolute Total Dynamic Sagittal Moment at Absolute Maximum Sagittal Trunk Angle – The Total Dynamic Sagittal Moment in Newton-meters at the time of the occurrence of the maximum value of the absolute sagittal trunk angle.

Absolute Maximum Y-axis Dynamic Lift Moment – The maximum of the absolute value of the Z force times the X moment arm over the duration of the entire exertion. Units are Newton meters.

Absolute Y-axis Dynamic Lift Moment at Absolute Maximum Sagittal Trunk Angle – The Y-axis Dynamic Lift Moment in Newton-meters at the time of the occurrence of the maximum value of the absolute sagittal trunk angle.

Absolute Maximum Y-axis Static Lift Moment – The maximum of the absolute value of the instantaneous Box Weight times the X moment arm over the duration of the entire exertion. Units are Newton meters.

Absolute Y-axis Static Lift Moment at Absolute Maximum Sagittal Trunk Angle – The Y-axis Static Lift Moment in Newton-meters at the time of the occurrence of the maximum value of the absolute sagittal trunk angle.

Average Box Weight – Force due to the weight of the box averaged over the duration of the exertion in Newtons.

Average Dynamic Z Force – The average Z force on the hands in Newtons over the duration of the entire exertion.

Box Asymmetry at Absolute Maximum Resultant Dynamic Moment – The Box Asymmetry in degrees at the time of occurrence of the Absolute Maximum Resultant Dynamic Moment

Box Asymmetry at Absolute Maximum X-axis Dynamic Lift Moment – The Box Asymmetry in degrees at the time of occurrence of the Absolute Maximum X-axis Dynamic Lift Moment

Box Asymmetry at Absolute Maximum X-axis Static Lift Moment – The Box Asymmetry in degrees at the time of occurrence of the Absolute Maximum X-axis Static Lift Moment

Box Asymmetry at Absolute Maximum XY*Lift Dynamic Moment – The Box Asymmetry in degrees at the time of occurrence of the Absolute Maximum XY*Lift Dynamic Moment

Box Asymmetry at Absolute Maximum XY*Lift Static Moment – The Box Asymmetry in degrees at the time of occurrence of the Absolute Maximum XY*Lift Static Moment.

Box Asymmetry at Absolute Maximum Total Dynamic Sagittal Moment – The Box Asymmetry in degrees at the time of occurrence of the Absolute Maximum Total Dynamic Sagittal Moment.

Box Asymmetry at Absolute Maximum Y-axis Dynamic Lift Moment – The Box Asymmetry in degrees at the time of occurrence of the Absolute Maximum Y-axis Dynamic Lift Moment.

Box Asymmetry at Absolute Maximum Y-axis Static Lift Moment – The Box Asymmetry in degrees at the time of occurrence of the Absolute Maximum Y-axis Static Lift Moment.

Box Backward Y Acceleration at Absolute Maximum Resultant Dynamic Moment – The Box Backward Y Acceleration in meters per second² at the time of occurrence of the Absolute Maximum Resultant Dynamic Moment.

Box Backward Y Acceleration at Absolute Maximum X-axis Dynamic Moment – The Box Backward Y Acceleration in meters per second² at the time of occurrence of the Absolute Maximum X-axis Dynamic Moment.

Box Backward Y Acceleration at Absolute Maximum X-axis Static Moment – The Box Backward Y Acceleration in meters per second² at the time of occurrence of the Absolute Maximum X-axis Static Moment.

Box Backward Y Acceleration at Absolute Maximum XY*Lift Dynamic Moment – The Box Backward Y Acceleration in meters per second² at the time of occurrence of the Absolute Maximum XY*Lift Dynamic Moment.

Box Backward Y Acceleration at Absolute Maximum XY*Lift Static Moment – The Box Backward Y Acceleration in meters per second² at the time of occurrence of the Absolute Maximum XY*Lift Static Moment.

Box Backward Y Acceleration at Absolute Maximum Total Dynamic Sagittal Moment –

The Box Backward Y Acceleration in meters per second² at the time of occurrence of the Absolute Maximum Total Dynamic Sagittal Moment.

Box Backward Y Acceleration at Absolute Maximum Y-axis Dynamic Moment – The Box

Backward Y Acceleration in meters per second² at the time of occurrence of the Absolute Maximum Y-axis Dynamic Moment.

Box Backward Y Acceleration at Absolute Maximum Y-axis Static Moment – The Box

Backward Y Acceleration in meters per second² at the time of occurrence of the Absolute Maximum Y-axis Static Moment.

Box Down Z Acceleration at Absolute Maximum Resultant Dynamic Moment – The Box

Down Z Acceleration in meters per second² at the time of occurrence of the Absolute Maximum Resultant Dynamic Moment.

Box Down Z Acceleration at Absolute Maximum X-axis Dynamic Moment – The Box Down

Z Acceleration in meters per second² at the time of occurrence of the Absolute Maximum X-axis Dynamic Moment.

Box Down Z Acceleration at Absolute Maximum X-axis Static Moment – The Box Down Z

Acceleration in meters per second² at the time of occurrence of the Absolute Maximum X-axis Static Moment.

Box Down Z Acceleration at Absolute Maximum XY*Lift Dynamic Moment – The Box

Down Z Acceleration in meters per second² at the time of occurrence of the Absolute Maximum XY*Lift Dynamic Moment.

Box Down Z Acceleration at Absolute Maximum XY*Lift Static Moment – The Box Down

Z Acceleration in meters per second² at the time of occurrence of the Absolute Maximum XY*Lift Static Moment.

Box Down Z Acceleration at Absolute Maximum Total Dynamic Sagittal Moment – The

Box Down Z Acceleration in meters per second² at the time of occurrence of the Absolute Maximum Total Dynamic Sagittal Moment.

Box Down Z Acceleration at Absolute Maximum Y-axis Dynamic Moment – The Box Down

Z Acceleration in meters per second² at the time of occurrence of the Absolute Maximum Y-axis Dynamic Moment.

Box Down Z Acceleration at Absolute Maximum Y-axis Static Moment – The Box Down Z

Acceleration in meters per second² at the time of occurrence of the Absolute Maximum Y-axis Static Moment.

Box Forward Y Acceleration at Absolute Maximum Resultant Dynamic Moment – The Box

Forward Y Acceleration in meters per second² at the time of occurrence of the Absolute Maximum Resultant Dynamic Moment.

Box Forward Y Acceleration at Absolute Maximum X-axis Dynamic Moment – The Box

Forward Y Acceleration in meters per second² at the time of occurrence of the Absolute Maximum X-axis Dynamic Moment.

Box Forward Y Acceleration at Absolute Maximum X-axis Static Moment – The Box Forward Y Acceleration in meters per second² at the time of occurrence of the Absolute Maximum X-axis Static Moment.

Box Forward Y Acceleration at Absolute Maximum XY*Lift Dynamic Moment – The Box Forward Y Acceleration in meters per second² at the time of occurrence of the Absolute Maximum XY*Lift Dynamic Moment.

Box Forward Y Acceleration at Absolute Maximum XY*Lift Static Moment – The Box Forward Y Acceleration in meters per second² at the time of occurrence of the Absolute Maximum XY*Lift Static Moment.

Box Forward Y Acceleration at Absolute Maximum Total Dynamic Sagittal Moment – The Box Forward Y Acceleration in meters per second² at the time of occurrence of the Absolute Maximum Total Dynamic Sagittal Moment.

Box Forward Y Acceleration at Absolute Maximum Y-axis Dynamic Moment – The Box Forward Y Acceleration in meters per second² at the time of occurrence of the Absolute Maximum Y-axis Dynamic Moment.

Box Forward Y Acceleration at Absolute Maximum Y-axis Static Moment – The Box Forward Y Acceleration in meters per second² at the time of occurrence of the Absolute Maximum Y-axis Static Moment.

Box Forwards Y Velocity at Destination – The Box Forward Y Acceleration in meters per second² at the end of the exertion.

Box Leftward X Acceleration at Absolute Maximum Resultant Dynamic Moment – The Box Leftward X Acceleration in meters per second² at the time of occurrence of the Absolute Maximum Resultant Dynamic Moment.

Box Leftward X Acceleration at Absolute Maximum X-axis Dynamic Moment – The Box Leftward X Acceleration in meters per second² at the time of occurrence of the Absolute Maximum X-axis Dynamic Moment.

Box Leftward X Acceleration at Absolute Maximum X-axis Static Moment – The Box Leftward X Acceleration in meters per second² at the time of occurrence of the Absolute Maximum X-axis Static Moment.

Box Leftward X Acceleration at Absolute Maximum XY*Lift Dynamic Moment – The Box Leftward X Acceleration in meters per second² at the time of occurrence of the Absolute Maximum XY*Lift Dynamic Moment.

Box Leftward X Acceleration at Absolute Maximum XY*Lift Static Moment – The Box Leftward X Acceleration in meters per second² at the time of occurrence of the Absolute Maximum XY*Lift Static Moment.

Box Leftward X Acceleration at Absolute Maximum Total Dynamic Sagittal Moment – The Box Leftward X Acceleration in meters per second² at the time of occurrence of the Absolute Maximum Total Dynamic Sagittal Moment.

Box Leftward X Acceleration at Absolute Maximum Y-axis Dynamic Moment – The Box Leftward X Acceleration in meters per second² at the time of occurrence of the Absolute Maximum Y-axis Dynamic Moment.

Box Leftward X Acceleration at Absolute Maximum Y-axis Static Moment – The Box Leftward X Acceleration in meters per second² at the time of occurrence of the Absolute Maximum Y-axis Static Moment.

Box Rightward X Acceleration at Absolute Maximum Resultant Dynamic Moment – The Box Rightward X Acceleration in meters per second² at the time of occurrence of the Absolute Maximum Resultant Dynamic Moment.

Box Rightward X Acceleration at Absolute Maximum X-axis Dynamic Moment – The Box Rightward X Acceleration in meters per second² at the time of occurrence of the Absolute Maximum X-axis Dynamic Moment.

Box Rightward X Acceleration at Absolute Maximum X-axis Static Moment – The Box Rightward X Acceleration in meters per second² at the time of occurrence of the Absolute Maximum X-axis Static Moment.

Box Rightward X Acceleration at Absolute Maximum XY*Lift Dynamic Moment – The Box Rightward X Acceleration in meters per second² at the time of occurrence of the Absolute Maximum XY*Lift Dynamic Moment.

Box Rightward X Acceleration at Absolute Maximum XY*Lift Static Moment – The Box Rightward X Acceleration in meters per second² at the time of occurrence of the Absolute Maximum XY*Lift Static Moment.

Box Rightward X Acceleration at Absolute Maximum Total Dynamic Sagittal Moment – The Box Rightward X Acceleration in meters per second² at the time of occurrence of the Absolute Maximum Total Dynamic Sagittal Moment.

Box Rightward X Acceleration at Absolute Maximum Y-axis Dynamic Moment – The Box Rightward X Acceleration in meters per second² at the time of occurrence of the Absolute Maximum Y-axis Dynamic Moment.

Box Rightward X Acceleration at Absolute Maximum Y-axis Static Moment – The Box Rightward X Acceleration in meters per second² at the time of occurrence of the Absolute Maximum Y-axis Static Moment.

Box Up Z Acceleration at Absolute Maximum Resultant Dynamic Moment – The Box Up Z Acceleration in meters per second² at the time of occurrence of the Absolute Maximum Resultant Dynamic Moment.

Box Up Z Acceleration at Absolute Maximum X-axis Dynamic Moment – The Box Up Z Acceleration in meters per second² at the time of occurrence of the Absolute Maximum X-axis Dynamic Moment.

Box Up Z Acceleration at Absolute Maximum X-axis Static Moment – The Box Up Z Acceleration in meters per second² at the time of occurrence of the Absolute Maximum X-axis Static Moment.

Box Up Z Acceleration at Absolute Maximum XY*Lift Dynamic Moment – The Box Up Z Acceleration in meters per second² at the time of occurrence of the Absolute Maximum XY*Lift Dynamic Moment.

Box Up Z Acceleration at Absolute Maximum XY*Lift Static Moment – The Box Up Z Acceleration in meters per second² at the time of occurrence of the Absolute Maximum XY*Lift Static Moment.

Box Up Z Acceleration at Absolute Maximum Total Dynamic Sagittal Moment – The Box Up Z Acceleration in meters per second² at the time of occurrence of the Absolute Maximum Total Dynamic Sagittal Moment.

Box Up Z Acceleration at Absolute Maximum Y-axis Dynamic Moment – The Box Up Z Acceleration in meters per second² at the time of occurrence of the Absolute Maximum Y-axis Dynamic Moment.

Box Up Z Acceleration at Absolute Maximum Y-axis Static Moment – The Box Up Z Acceleration in meters per second² at the time of occurrence of the Absolute Maximum Y-axis Static Moment.

Duration – The time in seconds of an exertion. An exertion starts when each hand simultaneously experiences more than 6.675 N of force and ends when this is no longer true.

Duration of non-load exposure – The time between exertions in seconds.

End Asymmetry – The asymmetry of the box with respect to the subject at the end of the exertion in degrees. 0 degrees is defined as the subject's Right.

End Box Height – The height of the box off of the floor at the start of the exertion in meters.

End XY Moment Arm – The resultant of the X and Y moment arms at the end of an exertion in meters.

Frequency – The number of exertions in a minute.

Integrated Absolute Dynamic Y Force – Cumulative Y force on the hands in Newtons integrated over the duration of the entire exertion. Technically, this is integrated over time and so should be Newton * Seconds. However, seconds are not expressed in the final units as the intent of this variable is to convey a sense of the “dose” of exposure.

Integrated Absolute Dynamic YZ Force – Cumulative resultant of Y and Z forces on the hands in Newtons integrated over the duration of the entire exertion. Technically, this is integrated over time and so should be Newton * Seconds. However, seconds are not expressed in the final units as the intent of this variable is to convey a sense of the “dose” of exposure.

Integrated Absolute X-axis Dynamic Moment – Cumulative X-Axis Dynamic Moment in Newton-meters integrated over the duration of the entire exertion. Technically, this is integrated over time and so should be Newton * Meter * Seconds. However, seconds are not expressed in the final units as the intent of this variable is to convey a sense of the “dose” of exposure.

Integrated Absolute X-axis Static Lift Moment – Cumulative X-Axis Static Moment in Newton-meters integrated over the duration of the entire exertion. Technically, this is integrated over time and so should be Newton * Meter * Seconds. However, seconds are not expressed in the final units as the intent of this variable is to convey a sense of the “dose” of exposure.

Integrated Absolute XY*Lift Dynamic Moment – Cumulative XY*Lift Dynamic Moment in Newton-meters integrated over the duration of the entire exertion. Technically, this is integrated over time and so should be Newton * Meter * Seconds. However, seconds are not expressed in the final units as the intent of this variable is to convey a sense of the “dose” of exposure.

Integrated Absolute XY*Lift Static Moment – Cumulative XY*Lift Static Moment in Newton-meters integrated over the duration of the entire exertion. Technically, this is integrated over time and so should be Newton * Meter * Seconds. However, seconds are not expressed in the final units as the intent of this variable is to convey a sense of the “dose” of exposure.

Integrated Absolute Y-axis Dynamic Moment – Cumulative Y-Axis Dynamic Moment in Newton-meters integrated over the duration of the entire exertion. Technically, this is integrated over time and so should be Newton * Meter * Seconds. However, seconds are not expressed in the final units as the intent of this variable is to convey a sense of the “dose” of exposure.

Integrated Absolute Y-axis Static Lift Moment – Cumulative Y-Axis Static Moment in Newton-meters integrated over the duration of the entire exertion. Technically, this is integrated over time and so should be Newton * Meter * Seconds. However, seconds are not expressed in the final units as the intent of this variable is to convey a sense of the “dose” of exposure.

Integrated Box Backwards Y Velocity – Cumulative Box Backwards Y Velocity exposure in meters per second integrated over the duration of the entire exertion. Technically, this is integrated over time and so should be (Meter / Second) * Seconds = meters. However, for clarity, the variable’s original units are preserved in the final units as the intent of this variable is to convey a sense of the “dose” of exposure.

Integrated Box Down Z Velocity – Cumulative Box Down Z Velocity exposure in meters per second integrated over the duration of the entire exertion. Technically, this is integrated over time and so should be (Meter / Second) * Seconds = meters. However, for clarity, the variable’s original units are preserved in the final units as the intent of this variable is to convey a sense of the “dose” of exposure.

Integrated Box Forwards Y Velocity – Cumulative Box Forwards Y Velocity exposure in meters per second integrated over the duration of the entire exertion. Technically, this is integrated over time and so should be (Meter / Second) * Seconds = meters. However, for clarity, the variable’s original units are preserved in the final units as the intent of this variable is to convey a sense of the “dose” of exposure.

Integrated Box Leftwards X Velocity – Cumulative Box Leftwards X Velocity exposure in meters per second integrated over the duration of the entire exertion. Technically, this is integrated over time and so should be (Meter / Second) * Seconds = meters. However, for clarity, the variable’s original units are preserved in the final units as the intent of this variable is to convey a sense of the “dose” of exposure.

Integrated Box Resultant Acceleration Without Gravity – Cumulative Resultant Acceleration exposure in meters per second per second integrated over the duration of the entire exertion. The acceleration due to gravity has been removed from this resultant. Technically, this is integrated

over time and so should be $(\text{Meter} / \text{Second}^2) * \text{Seconds} = \text{meters/second}$. However, for clarity, the variable's original units are preserved in the final units as the intent of this variable is to convey a sense of the "dose" of exposure.

Integrated Box Resultant Velocity – Cumulative Box Resultant Velocity exposure in meters per second integrated over the duration of the entire exertion. Technically, this is integrated over time and so should be $(\text{Meter} / \text{Second}) * \text{Seconds} = \text{meters}$. However, for clarity, the variable's original units are preserved in the final units as the intent of this variable is to convey a sense of the "dose" of exposure.

Integrated Box Rightwards X Velocity – Cumulative Box Rightwards X Velocity exposure in meters per second integrated over the duration of the entire exertion. Technically, this is integrated over time and so should be $(\text{Meter} / \text{Second}) * \text{Seconds} = \text{meters}$. However, for clarity, the variable's original units are preserved in the final units as the intent of this variable is to convey a sense of the "dose" of exposure.

Integrated Box Up Z Velocity – Cumulative Box Up Z Velocity exposure in meters per second integrated over the duration of the entire exertion. Technically, this is integrated over time and so should be $(\text{Meter} / \text{Second}) * \text{Seconds} = \text{meters}$. However, for clarity, the variable's original units are preserved in the final units as the intent of this variable is to convey a sense of the "dose" of exposure.

Integrated Absolute Box Weight – Cumulative force due to the absolute weight of the box integrated over the duration of the exertion in Newtons. Technically, this is integrated over time and so should be $\text{Newton} * \text{Seconds}$. However, for clarity, the variable's original units are preserved in the final units as the intent of this variable is to convey a sense of the "dose" of exposure.

Integrated Box X Acceleration – Cumulative Box X Acceleration (increase in velocity) exposure in meters per second per second integrated over the duration of the entire exertion. Technically, this is integrated over time and so should be $(\text{Meter} / \text{Second}^2) * \text{Seconds} = \text{meters} / \text{second}$. However, for clarity, the variable's original units are preserved in the final units as the intent of this variable is to convey a sense of the "dose" of exposure.

Integrated Box X Deceleration – Cumulative Box X Deceleration (decrease in velocity) exposure in meters per second per second integrated over the duration of the entire exertion. Technically, this is integrated over time and so should be $(\text{Meter} / \text{Second}^2) * \text{Seconds} = \text{meters} / \text{second}$. However, for clarity, the variable's original units are preserved in the final units as the intent of this variable is to convey a sense of the "dose" of exposure.

Integrated Box Y Acceleration – Cumulative Box Y Acceleration (increase in velocity) exposure in meters per second per second integrated over the duration of the entire exertion. Technically, this is integrated over time and so should be $(\text{Meter} / \text{Second}^2) * \text{Seconds} = \text{meters} / \text{second}$. However, for clarity, the variable's original units are preserved in the final units as the intent of this variable is to convey a sense of the "dose" of exposure.

Integrated Box Y Deceleration – Cumulative Box Y Deceleration (decrease in velocity) exposure in meters per second per second integrated over the duration of the entire exertion.

Technically, this is integrated over time and so should be $(\text{Meter} / \text{Second}^2) * \text{Seconds} = \text{meters} / \text{second}$. However, for clarity, the variable's original units are preserved in the final units as the intent of this variable is to convey a sense of the "dose" of exposure.

Integrated Box Z Acceleration – Cumulative Box Z Acceleration (increase in velocity)

exposure in meters per second per second integrated over the duration of the entire exertion.

Technically, this is integrated over time and so should be $(\text{Meter} / \text{Second}^2) * \text{Seconds} = \text{meters} / \text{second}$. However, for clarity, the variable's original units are preserved in the final units as the intent of this variable is to convey a sense of the "dose" of exposure.

Integrated Box Z Deceleration – Cumulative Box Z Deceleration (decrease in velocity)

exposure in meters per second per second integrated over the duration of the entire exertion.

Technically, this is integrated over time and so should be $(\text{Meter} / \text{Second}^2) * \text{Seconds} = \text{meters} / \text{second}$. However, for clarity, the variable's original units are preserved in the final units as the intent of this variable is to convey a sense of the "dose" of exposure.

Integrated Dynamic Z Force – Cumulative Z force on the hands integrated over the duration of the exertion in Newtons. Technically, this is integrated over time and so should be $\text{Newton} * \text{Seconds}$.

However, for clarity, the variable's original units are preserved in the final units as the intent of this variable is to convey a sense of the "dose" of exposure.

Integrated Extension Sagittal Velocity – Cumulative Sagittal Extension Velocity in degrees

per second integrated over the duration of the entire exertion. Technically, this is integrated over

time and so should be $(\text{Degrees} / \text{Second}) * \text{Seconds} = \text{degrees}$. However, for clarity, the variable's original units are preserved in the final units as the intent of this variable is to convey a sense of the "dose" of exposure.

Integrated Flexion Sagittal Velocity – Cumulative Sagittal Flexion Velocity in degrees per

second integrated over the duration of the entire exertion. Technically, this is integrated over

time and so should be $(\text{Degrees} / \text{Second}) * \text{Seconds} = \text{degrees}$. However, for clarity, the variable's original units are preserved in the final units as the intent of this variable is to convey a sense of the "dose" of exposure.

Integrated Lateral Acceleration – Cumulative Lateral Acceleration (increase in velocity)

exposure in degrees per second per second integrated over the duration of the entire exertion.

Technically, this is integrated over time and so should be $(\text{Degrees} / \text{Second}^2) * \text{Seconds} = \text{degrees} / \text{second}$. However, for clarity, the variable's original units are preserved in the final units as the intent of this variable is to convey a sense of the "dose" of exposure.

Integrated Lateral Deceleration – Cumulative Lateral Deceleration (increase in velocity)

exposure in degrees per second per second integrated over the duration of the entire exertion.

Technically, this is integrated over time and so should be $(\text{Degrees} / \text{Second}^2) * \text{Seconds} = \text{degrees} / \text{second}$. However, for clarity, the variable's original units are preserved in the final units as the intent of this variable is to convey a sense of the "dose" of exposure.

Integrated Leftwards Lateral Trunk Angle – Cumulative exposure to left lateral bending in

degrees integrated over the duration of the entire exertion. Technically, this is integrated over

time and so should be $\text{Degrees} * \text{Seconds}$. However, for clarity, the variable's original units are

preserved in the final units as the intent of this variable is to convey a sense of the “dose” of exposure.

Integrated Leftwards Lateral Velocity – Cumulative exposure to left lateral bending velocity in degrees per second integrated over the duration of the entire exertion. Technically, this is integrated over time and so should be $(\text{Degrees} / \text{Second}) * \text{Seconds} = \text{degrees}$. However, for clarity, the variable’s original units are preserved in the final units as the intent of this variable is to convey a sense of the “dose” of exposure.

Integrated Resultant Dynamic Moment – Cumulative exposure to Resultant Dynamic Moment in Newton-meters integrated over the duration of the entire exertion. Technically, this is integrated over time and so should be $(\text{Newton} * \text{meters}) * \text{Seconds}$. However, for clarity, the variable’s original units are preserved in the final units as the intent of this variable is to convey a sense of the “dose” of exposure.

Integrated Rightwards Lateral Trunk Angle – Cumulative exposure to right lateral bending in degrees integrated over the duration of the entire exertion. Technically, this is integrated over time and so should be $\text{Degrees} * \text{Seconds}$. However, for clarity, the variable’s original units are preserved in the final units as the intent of this variable is to convey a sense of the “dose” of exposure.

Integrated Rightwards Lateral Velocity – Cumulative exposure to right lateral bending velocity in degrees per second integrated over the duration of the entire exertion. Technically, this is integrated over time and so should be $(\text{Degrees} / \text{Second}) * \text{Seconds} = \text{degrees}$. However, for clarity, the variable’s original units are preserved in the final units as the intent of this variable is to convey a sense of the “dose” of exposure.

Integrated Sagittal Acceleration – Cumulative Sagittal Acceleration (increase in velocity) exposure in degrees per second per second integrated over the duration of the entire exertion. Technically, this is integrated over time and so should be $(\text{Degrees} / \text{Second}^2) * \text{Seconds} = \text{degrees} / \text{second}$. However, for clarity, the variable’s original units are preserved in the final units as the intent of this variable is to convey a sense of the “dose” of exposure.

Integrated Sagittal Deceleration – Cumulative Sagittal Deceleration (increase in velocity) exposure in degrees per second per second integrated over the duration of the entire exertion. Technically, this is integrated over time and so should be $(\text{Degrees} / \text{Second}^2) * \text{Seconds} = \text{degrees} / \text{second}$. However, for clarity, the variable’s original units are preserved in the final units as the intent of this variable is to convey a sense of the “dose” of exposure.

Integrated Sagittal Trunk Angle – Cumulative exposure to sagittal bending in degrees integrated over the duration of the entire exertion. Technically, this is integrated over time and so should be $\text{Degree} * \text{Seconds}$. However, for clarity, the variable’s original units are preserved in the final units as the intent of this variable is to convey a sense of the “dose” of exposure.

Integrated Total Dynamic Sagittal Moment – Cumulative exposure to Total Dynamic Sagittal Moment in Newton-meters integrated over the duration of the entire exertion. Technically, this is integrated over time and so should be $(\text{Newton} * \text{meters}) * \text{Seconds}$. However, for clarity, the

variable's original units are preserved in the final units as the intent of this variable is to convey a sense of the "dose" of exposure.

Maximum Box Backwards Y Velocity – The maximum of the Box Velocity along the Y axis towards L5/S1 over the duration of the entire exertion. Velocity is calculated as the derivative of the acceleration measured at the handles. Units are meters per second.

Maximum Box Down Z Velocity – The maximum of the Box Velocity along the Z axis towards the floor over the duration of the entire exertion. Velocity is calculated as the derivative of the acceleration measured at the handles. Units are meters per second.

Maximum Box Forwards Y Velocity – The maximum of the Box Velocity along the Y axis away from L5/S1 over the duration of the entire exertion. Velocity is calculated as the derivative of the acceleration measured at the handles. Units are meters per second.

Maximum Box Leftwards X Velocity – The maximum of the Box Velocity along the X axis towards the subject's left over the duration of the entire exertion. Velocity is calculated as the derivative of the acceleration measured at the handles. Units are meters per second.

Maximum Box Rightwards X Velocity – The maximum of the Box Velocity along the X axis towards the subject's right over the duration of the entire exertion. Velocity is calculated as the derivative of the acceleration measured at the handles. Units are meters per second.

Maximum Box Up Z Velocity – The maximum of the Box Velocity along the Z axis away from the floor over the duration of the entire exertion. Velocity is calculated as the derivative of the acceleration measured at the handles. Units are meters per second.

Maximum Box X Acceleration – The maximum of the Box Acceleration along the X axis over the duration of the entire exertion. Acceleration is measured at the handles. Units are meters per second per second.

Maximum Box X Deceleration – The maximum of the Box Deceleration along the X axis over the duration of the entire exertion. Acceleration is measured at the handles. Units are meters per second per second.

Maximum Box Y Acceleration – The maximum of the Box Acceleration along the Y axis over the duration of the entire exertion. Acceleration is measured at the handles. Units are meters per second per second.

Maximum Box Y Deceleration – The maximum of the Box Deceleration along the Y axis over the duration of the entire exertion. Acceleration is measured at the handles. Units are meters per second per second.

Maximum Box Z Acceleration – The maximum of the Box Acceleration along the Z axis over the duration of the entire exertion. Acceleration is measured at the handles. Units are meters per second per second.

Maximum Box Z Deceleration – The maximum of the Box Deceleration along the Y axis over the duration of the entire exertion. Acceleration is measured at the handles. Units are meters per second per second.

Maximum Dynamic Z Force – Maximum Z force on the hands in Newtons over the duration of the exertion.

Maximum Extension Sagittal Trunk Velocity – The maximum of the Sagittal Trunk Extension Velocity over the duration of the entire exertion. Velocity is the integral of Sagittal Trunk Angle. Units are degrees per second.

Maximum Flexion Sagittal Trunk Velocity – The maximum of the Sagittal Trunk Flexion Velocity over the duration of the entire exertion. Velocity is the integral of Sagittal Trunk Angle. Units are degrees per second.

Maximum Lateral Trunk Acceleration – The maximum of the Lateral Trunk Acceleration in either direction over the duration of the entire exertion. Acceleration is the integral of Lateral Trunk Velocity. Units are degrees per second per second.

Maximum Lateral Trunk Deceleration – The maximum of the Lateral Trunk Deceleration in either direction over the duration of the entire exertion. Acceleration is the integral of Lateral Trunk Velocity. Units are degrees per second per second.

Maximum Left Lateral Trunk Angle – The maximum of the subject's lateral bending to the subject's left over the duration of the entire exertion. Trunk angle is expressed relative to an upright standard condition. Units are degrees.

Maximum Leftwards Lateral Trunk Velocity – The maximum of the subject's lateral bending to the subject's left over the duration of the entire exertion. Velocity is the integral of position. Units are degrees per second.

Maximum Resultant Moment Arm – The resultant of the X, Y and Z moment arms over the duration of an exertion in meters.

Maximum Right Lateral Trunk Angle – The maximum of the subject's lateral bending to the subject's right over the duration of the entire exertion. Trunk angle is expressed relative to an upright standard condition. Units are degrees.

Maximum Rightwards Lateral Trunk Velocity – The maximum of the subject's lateral bending to the subject's right over the duration of the entire exertion. Velocity is the integral of position. Units are degrees per second.

Maximum Sagittal Trunk Acceleration – The maximum of the subject's Sagittal Acceleration over the duration of the entire exertion. Acceleration is the integral of velocity. Units are degrees per second per second.

Maximum Sagittal Trunk Deceleration – The maximum of the subject's Sagittal Deceleration over the duration of the entire exertion. Acceleration is the integral of velocity. Units are degrees per second per second.

Maximum XY Moment Arm – The maximum resultant of the X and Y moment arms over the duration of the exertion in meters.

Peak*Duration Absolute Box Weight – Maximum force due to the absolute weight of the box Peak*Duration over the duration of the exertion in Newtons. Technically, this is a variable * time and so should be Newton * seconds. However, for clarity, the variable's original units are preserved in the final units as the intent of this variable is to convey a sense of the “dose” of exposure.

Peak*Duration Absolute Dynamic Y Force – Maximum Y force on the hands in Newtons multiplied by the duration of the entire exertion. Technically, this is a variable * time and so should be Newton * seconds. However, for clarity, the variable's original units are preserved in the final units as the intent of this variable is to convey a sense of the "dose" of exposure.

Peak*Duration Absolute Dynamic YZ Force – Maximum resultant of Y and Z forces on the hands in Newtons multiplied by the duration of the entire exertion. Technically, this is a variable * time and so should be Newton * seconds. However, for clarity, the variable's original units are preserved in the final units as the intent of this variable is to convey a sense of the "dose" of exposure.

Peak*Duration Absolute Dynamic Z Force – Maximum Z force on the hands in Newtons multiplied by the duration of the entire exertion. Technically, this is a variable * time and so should be Newton * seconds. However, for clarity, the variable's original units are preserved in the final units as the intent of this variable is to convey a sense of the "dose" of exposure.

Peak*Duration Absolute X-axis Dynamic Moment – Maximum X-Axis Dynamic Moment in Newton-meters multiplied by the duration of the entire exertion. Technically, this is a variable * time and so should be Newton * Meter * Seconds. However, for clarity, the variable's original units are preserved in the final units as the intent of this variable is to convey a sense of the "dose" of exposure.

Peak*Duration Absolute X-axis Static Lift Moment – Maximum X-Axis Static Moment in Newton-meters multiplied by the duration of the entire exertion. Technically, this is a variable * time and so should be Newton * Meter * Seconds. However, for clarity, the variable's original units are preserved in the final units as the intent of this variable is to convey a sense of the "dose" of exposure.

Peak*Duration Absolute XY*Lift Dynamic Moment – Maximum XY*Lift Dynamic Moment in Newton-meters multiplied by the duration of the entire exertion. Technically, this is a variable * time and so should be Newton * Meter * Seconds. However, for clarity, the variable's original units are preserved in the final units as the intent of this variable is to convey a sense of the "dose" of exposure.

Peak*Duration Absolute XY*Lift Static Moment – Maximum XY*Lift Static Moment in Newton-meters multiplied by the duration of the entire exertion. Technically, this is a variable * time and so should be Newton * Meter * Seconds. However, for clarity, the variable's original units are preserved in the final units as the intent of this variable is to convey a sense of the "dose" of exposure.

Peak*Duration Absolute Y-axis Dynamic Moment – Maximum Y-Axis Dynamic Moment in Newton-meters multiplied by the duration of the entire exertion. Technically, this is a variable * time and so should be Newton * Meter * Seconds. However, for clarity, the variable's original units are preserved in the final units as the intent of this variable is to convey a sense of the "dose" of exposure.

Peak*Duration Absolute Y-axis Static Lift Moment – Maximum Y-Axis Static Moment in Newton-meters multiplied by the duration of the entire exertion. Technically, this is a variable *

time and so should be Newton * Meter * Seconds. However, for clarity, the variable's original units are preserved in the final units as the intent of this variable is to convey a sense of the "dose" of exposure.

Peak*Duration Box Resultant Acceleration Without Gravity – Maximum Absolute Resultant Acceleration exposure in meters per second per second multiplied by the duration of the entire exertion. The acceleration due to gravity has been removed from this resultant. Technically, this is a variable * time and so should be $(\text{Meter} / \text{Second}^2) * \text{Seconds} = \text{Meters/Second}$. However, for clarity, the variable's original units are preserved in the final units as the intent of this variable is to convey a sense of the "dose" of exposure.

Peak*Duration Box Resultant Velocity – Maximum Absolute Box Resultant Velocity exposure in meters per second multiplied by the duration of the entire exertion. Technically, this is a variable * time and so should be $(\text{Meter} / \text{Second}) * \text{Seconds} = \text{Meters}$. However, for clarity, the variable's original units are preserved in the final units as the intent of this variable is to convey a sense of the "dose" of exposure.

Peak*Duration Box X Acceleration – Maximum Absolute Box X Acceleration exposure in meters per second per second multiplied by the duration of the entire exertion. Technically, this is a variable * time and so should be $(\text{Meter} / \text{Second}^2) * \text{Seconds} = \text{Meters/Second}$. However, for clarity, the variable's original units are preserved in the final units as the intent of this variable is to convey a sense of the "dose" of exposure.

Peak*Duration Box X Velocity – Maximum Absolute Box X Velocity exposure in meters per second multiplied by the duration of the entire exertion. Technically, this is a variable * time and so should be $(\text{Meter} / \text{Second}) * \text{Seconds} = \text{Meters}$. However, for clarity, the variable's original units are preserved in the final units as the intent of this variable is to convey a sense of the "dose" of exposure.

Peak*Duration Box Y Acceleration – Maximum Absolute Box Y Acceleration exposure in meters per second per second multiplied by the duration of the entire exertion. Technically, this is a variable * time and so should be $(\text{Meter} / \text{Second}^2) * \text{Seconds} = \text{Meters/Second}$. However, for clarity, the variable's original units are preserved in the final units as the intent of this variable is to convey a sense of the "dose" of exposure.

Peak*Duration Box Y Velocity – Maximum Absolute Box Y Velocity exposure in meters per second multiplied by the duration of the entire exertion. Technically, this is a variable * time and so should be $(\text{Meter} / \text{Second}) * \text{Seconds} = \text{Meters}$. However, for clarity, the variable's original units are preserved in the final units as the intent of this variable is to convey a sense of the "dose" of exposure.

Peak*Duration Box Z Acceleration – Maximum Absolute Box Z Acceleration exposure in meters per second per second multiplied by the duration of the entire exertion. Technically, this is a variable * time and so should be $(\text{Meter} / \text{Second}^2) * \text{Seconds} = \text{Meters/Second}$. However, for clarity, the variable's original units are preserved in the final units as the intent of this variable is to convey a sense of the "dose" of exposure.

Peak*Duration Box Z Velocity – Maximum Absolute Box Z Velocity exposure in meters per second multiplied by the duration of the entire exertion. Technically, this is a variable * time and so should be (Meter / Second) * Seconds = Meters. However, for clarity, the variable's original units are preserved in the final units as the intent of this variable is to convey a sense of the “dose” of exposure.

Peak*Duration Lateral Acceleration – Maximum Absolute Lateral Acceleration exposure in degrees per second per second multiplied by the duration of the entire exertion. Technically, this is a variable * time and so should be (Meter / Second²) * Seconds = Meters/Second. However, for clarity, the variable's original units are preserved in the final units as the intent of this variable is to convey a sense of the “dose” of exposure.

Peak*Duration Lateral Trunk Angle – Maximum Absolute Lateral Trunk Angle exposure in degrees multiplied by the duration of the entire exertion. Technically, this is a variable * time and so should be Degrees * Seconds. However, for clarity, the variable's original units are preserved in the final units as the intent of this variable is to convey a sense of the “dose” of exposure.

Peak*Duration Lateral Velocity – Maximum Absolute Lateral Velocity exposure in degrees per second multiplied by the duration of the entire exertion. Technically, this is a variable * time and so should be (Degree / Second) * Seconds = Degrees. However, for clarity, the variable's original units are preserved in the final units as the intent of this variable is to convey a sense of the “dose” of exposure.

Peak*Duration Resultant Dynamic Moment – Maximum exposure to Resultant Dynamic Moment in Newton-meters multiplied by the duration of the entire exertion. Technically, this is a variable * time and so should be (Newton * Meters) * Seconds. However, for clarity, the variable's original units are preserved in the final units as the intent of this variable is to convey a sense of the “dose” of exposure.

Peak*Duration Sagittal Acceleration – Maximum Absolute Sagittal Acceleration exposure in degrees per second per second multiplied by the duration of the entire exertion. Technically, this is a variable * time and so should be (Meter / Second²) * Seconds = Meters/Second. However, for clarity, the variable's original units are preserved in the final units as the intent of this variable is to convey a sense of the “dose” of exposure.

Peak*Duration Sagittal Trunk Angle – Maximum Sagittal Trunk Angle in degrees multiplied by the duration of the entire exertion. Technically, this is a variable * time and so should be Degrees * Seconds. However, for clarity, the variable's original units are preserved in the final units as the intent of this variable is to convey a sense of the “dose” of exposure.

Peak*Duration Sagittal Velocity – Maximum Absolute Sagittal Velocity exposure in degrees per second multiplied by the duration of the entire exertion. Technically, this is a variable * time and so should be (Degree / Second) * Seconds = Degrees. However, for clarity, the variable's original units are preserved in the final units as the intent of this variable is to convey a sense of the “dose” of exposure.

Peak*Duration Total Dynamic Sagittal Moment – Maximum exposure to Total Dynamic Sagittal Moment in Newton-meters multiplied by the duration of the entire exertion. Technically, this is a variable * time and so should be (Newton * Meters) * Seconds. However, for clarity, the variable's original units are preserved in the final units as the intent of this variable is to convey a sense of the “dose” of exposure.

Percent Time of Absolute Maximum Box Resultant Acceleration Without Gravity – The percentage of time, measured from the beginning of the exertion, at which the maximum of the absolute value of the Box Resultant Acceleration Without Gravity occurs.

Percent Time of Absolute Maximum Box Resultant Velocity – The percentage of time, measured from the beginning of the exertion, at which the maximum of the absolute value of the Box Resultant Velocity occurs.

Percent Time of Absolute Maximum Dynamic Y Force – The percentage of time, measured from the beginning of the exertion, at which the maximum of the absolute value of the Dynamic Y Force occurs.

Percent Time of Absolute Maximum Dynamic YZ Force – The percentage of time, measured from the beginning of the exertion, at which the maximum of the absolute value of the resultant Y and Z forces on the hands occurs.

Percent Time of Absolute Maximum Resultant Dynamic Moment – The percentage of time, measured from the beginning of the exertion, at which the maximum of the absolute value of the Resultant Dynamic Moment occurs.

Percent Time of Absolute Maximum Sagittal Trunk Angle – The percentage of time, measured from the beginning of the exertion, at which the maximum of the absolute value of the Sagittal Trunk Angle occurs.

Percent Time of Absolute Maximum X-axis Dynamic Lift Moment – The percentage of time, measured from the beginning of the exertion, at which the maximum of the absolute value of the X-axis Dynamic Lift Moment occurs.

Percent Time of Absolute Maximum X-axis Static Lift Moment – The percentage of time, measured from the beginning of the exertion, at which the maximum of the absolute value of the X-axis Static Lift Moment occurs.

Percent Time of Absolute Maximum XY*Lift Dynamic Moment – The percentage of time, measured from the beginning of the exertion, at which the maximum of the absolute value of the XY*Lift Dynamic Moment occurs.

Percent Time of Absolute Maximum XY*Lift Static Moment – The percentage of time, measured from the beginning of the exertion, at which the maximum of the absolute value of the X* Lift Static Lift Moment occurs.

Percent Time of Absolute Maximum Total Dynamic Sagittal Moment – The percentage of time, measured from the beginning of the exertion, at which the maximum of the absolute value of the Total Dynamic Sagittal Moment occurs.

Percent Time of Absolute Maximum Y-axis Dynamic Lift Moment – The percentage of time, measured from the beginning of the exertion, at which the maximum of the absolute value of the Y-axis Dynamic Lift Moment occurs.

Percent Time of Absolute Maximum Y-axis Static Lift Moment – The percentage of time, measured from the beginning of the exertion, at which the maximum of the absolute value of the Y-axis Static Lift Moment occurs.

Percent Time of Maximum Box Backwards Y Velocity – The percentage of time, measured from the beginning of the exertion, at which the maximum value of the Box Backwards Y Velocity occurs.

Percent Time of Maximum Box Down Z Velocity – The percentage of time, measured from the beginning of the exertion, at which the maximum value of the Box Down Z Velocity occurs.

Percent Time of Maximum Box Forwards Y Velocity – The percentage of time, measured from the beginning of the exertion, at which the maximum value of the Box Forwards Y Velocity occurs.

Percent Time of Maximum Box Leftwards X Velocity – The percentage of time, measured from the beginning of the exertion, at which the maximum value of the Box Leftwards X Velocity occurs.

Percent Time of Maximum Box Rightwards X Velocity – The percentage of time, measured from the beginning of the exertion, at which the maximum value of the Box Rightwards X Velocity occurs.

Percent Time of Maximum Box Up Z Velocity – The percentage of time, measured from the beginning of the exertion, at which the maximum value of the Box Up Z Velocity occurs.

Percent Time of Maximum Box X Acceleration – The percentage of time, measured from the beginning of the exertion, at which the maximum value of the Box X Acceleration occurs.

Percent Time of Maximum Box X Deceleration – The percentage of time, measured from the beginning of the exertion, at which the maximum value of the Box X Deceleration occurs.

Percent Time of Maximum Box Y Acceleration – The percentage of time, measured from the beginning of the exertion, at which the maximum value of the Box Y Acceleration occurs.

Percent Time of Maximum Box Y Deceleration – The percentage of time, measured from the beginning of the exertion, at which the maximum value of the Box Y Deceleration occurs.

Percent Time of Maximum Box Z Acceleration – The percentage of time, measured from the beginning of the exertion, at which the maximum value of the Box Z Acceleration occurs.

Percent Time of Maximum Box Z Deceleration – The percentage of time, measured from the beginning of the exertion, at which the maximum value of the Box Z Deceleration occurs.

Percent Time of Maximum Dynamic Z Force – The percentage of time, measured from the beginning of the exertion, at which the maximum value of the Z force on the hands occurs.

Percent Time of Maximum Extension Sagittal Trunk Velocity – The percentage of time, measured from the beginning of the exertion, at which the maximum value of the Extension Sagittal Trunk Velocity occurs.

Percent Time of Maximum Flexion Sagittal Trunk Velocity – The percentage of time, measured from the beginning of the exertion, at which the maximum value of the Flexion Sagittal Trunk Velocity occurs.

Percent Time of Maximum Lateral Trunk Acceleration – The percentage of time, measured from the beginning of the exertion, at which the maximum value of the Lateral Trunk Acceleration occurs.

Percent Time of Maximum Lateral Trunk Deceleration – The percentage of time, measured from the beginning of the exertion, at which the maximum value of the Lateral Trunk Deceleration occurs.

Percent Time of Maximum Left Lateral Trunk Angle – The percentage of time, measured from the beginning of the exertion, at which the maximum value of the Lateral Trunk Angle occurs.

Percent Time of Maximum Leftwards Lateral Trunk Velocity – The percentage of time, measured from the beginning of the exertion, at which the maximum value of the Leftwards Lateral Trunk Velocity occurs.

Percent Time of Maximum Resultant Moment Arm – The percentage of time, measured from the beginning of the exertion, at which the maximum value of the Resultant Moment Arm occurs.

Percent Time of Maximum Right Lateral Trunk Angle – The percentage of time, measured from the beginning of the exertion, at which the maximum value of the Right Lateral Trunk Angle occurs.

Percent Time of Maximum Rightwards Lateral Trunk Velocity – The percentage of time, measured from the beginning of the exertion, at which the maximum value of the Rightwards Lateral Trunk Velocity occurs.

Percent Time of Maximum Sagittal Trunk Acceleration – The percentage of time, measured from the beginning of the exertion, at which the maximum value of the Sagittal Trunk Acceleration occurs.

Percent Time of Maximum Sagittal Trunk Deceleration – The percentage of time, measured from the beginning of the exertion, at which the maximum value of the Sagittal Trunk Deceleration occurs.

Percent Time of Maximum XY Moment Arm – The percentage of time, measured from the beginning of the exertion, at which the maximum value of the XY Moment Arm occurs.

Sagittal Trunk Angle at Absolute Maximum Resultant Dynamic Moment – The Sagittal Trunk Angle in degrees at the time of the Absolute Maximum Resultant Dynamic Moment.

Sagittal Trunk Angle at Absolute Maximum X-axis Dynamic Lift Moment – The Sagittal Trunk Angle in degrees at the time of the Absolute Maximum X-axis Dynamic Lift Moment.

Sagittal Trunk Angle at Absolute Maximum X-axis Static Lift Moment – The Sagittal Trunk Angle in degrees at the time of the Absolute Maximum X-axis Static Lift Moment.

Sagittal Trunk Angle at Absolute Maximum XY*Lift Dynamic Moment – The Sagittal Trunk Angle in degrees at the time of the Absolute Maximum XY*Lift Dynamic Moment.

Sagittal Trunk Angle at Absolute Maximum XY*Lift Static Moment – The Sagittal Trunk Angle in degrees at the time of the Absolute Maximum XY*Lift Static Moment.

Sagittal Trunk Angle at Absolute Maximum Total Dynamic Sagittal Moment – The Sagittal Trunk Angle in degrees at the time of the Absolute Maximum Total Dynamic Sagittal Moment.

Sagittal Trunk Angle at Absolute Maximum Y-axis Dynamic Lift Moment – The Sagittal Trunk Angle in degrees at the time of the Absolute Maximum Y-axis Dynamic Lift Moment.

Sagittal Trunk Angle at Absolute Maximum Y-axis Static Lift Moment – The Sagittal Trunk Angle in degrees at the time of the Absolute Maximum Y-axis Static Lift Moment.

Start Asymmetry – The asymmetry of the box with respect to the subject at the start of the exertion in degrees. 0 degrees is defined as the subject's Right.

Start Box Height – The height of the box off of the floor at the start of the exertion in meters.

Start XY Moment Arm – The resultant of the X and Y moment arms at the beginning of an exertion in meters.