Relating Musculoskeletal and Disability Conditions of Occupation-Induced Musculoskeletal Disorders to Non-occupational Congenital Disabilities

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Abstract Previous research indicates congenital disabilities may have similar physical outcomes to circumstantial disabilities encountered by occupational workers. This study attempted a preliminary mapping of musculoskeletal conditions of rice farmers to cerebral palsy (CP) patients. The farmers and CP patients were examined for lower extremity (LE) malalignment, perceived pain, and origin of structural damage. In agreement with farmers, CP participants exhibited foot pronation and knee valgus and perceived more hip and knee pain. In partial agreement with farmers, CP participant's pain origins included knee and ankle joints, and hamstring and gastrocnemius muscles, but not quadriceps muscle. The comparison showed that occupational and congenital disorder populations can be

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associated in terms of knee valgus prevalence, pain perception, and musculoskeletal impairments. Therefore, knee impairments and disorders should be emphasized for developing dual-use assistive technology to prevent further risk of LE injury for both farmers in work and CP populations in daily living tasks.

Keywords Circumstantial disability · Congenital disability · Musculoskeletal conditions · Structure malalignment · Pain

1 Introduction

Previous research has found that congenital disabilities may have similar physical and cognitive outcomes to circumstantial disabilities encountered by workers in occupational tasks [1, 2]. The nature of certain work environments can result in healthy workers exhibiting performance comparable to disabled populations. Many assistive technology (AT) designs for persons with disabilities have been applied to healthy workers who function in extreme environments. For example, Newell et al. [3] described the development of a multimodal workstation for computer task performance by persons with severe cognitive impairment along with assessment of use of the station by non-disabled users operating under high workload and safety-critical situations, such as air traffic controllers. Conversely, interventions designed to prevent worker disadvantage in extreme conditions may have utility for non-occupational disabled populations. Therefore, the study of physical conditions of occupation-induced musculoskeletal disorders (MSDs) could provide insight for interventions for congenital disabilities and support novel dual-use AT design.

Our previous research revealed a need for ergonomic interventions and ATs for Thai rice farmers [4, 5]. A MSD prevalence of 10.3–73.3 % was observed among Thai rice farmers [6]. We examined symptoms and causes of musculoskeletal and disability conditions of the lower extremities (LE) in 300 rice farmers (131 male and 169 female with age 45.13 ± 11.5) from Khon Kaen, Thailand. The participants had an average of 25.53 ± 11.5 years of experience with no less than 1 year of work in rice farming activities among all participants. Results showed a high prevalence of foot pronation (20.9 %) and knee valgus (18.5 %) [7]. Analysis of risk factors indicated that number of years of farming experience was associated with these specific malalignments (odds ratio = 1.04−1.06) [8]. Within the

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cultivation process, ergonomic screening results indicated that planting activity posed the highest risk for injury due to awkward posture, excessive force, and repetitive motion associated with this activity [9]. Related to this, farmers also perceived the greatest hip and knee pain (score of 6.1/10 and 3.6/10, respectively) during the planting activity [10]. Therefore, the planting process was selected as a target rice cultivation task for further analysis along with non-occupational congenital disabilities as bases for AT design. Physical examination of functional and diagnostic tests indicated that the origins of pain were from impairments of the knee joint (54.61 %) and lower extremity muscles [hamstring (36.2 %), quadriceps (30.4 %), and gastrocnemius (26.3 %)] [11].

In the present study, we attempted a preliminarily mapping of such occupation-related conditions to congenital disabilities, specifically musculoskeletal conditions of cerebral palsy (CP) patients. A CP population was selected due to CP orthopedic problems usually being overlooked or over-treated with surgery or heavy and uncomfortable bracing. Less invasive orthoses, similar to those used for treating work-related MSDs, may promote ease of daily living tasks. Moreover, several researchers have observed that many previous studies in disability engineering have been conducted with healthy populations under cognitive or motor restrictions. That is, disabilities are "simulated" to provide some insight for AT design and the validity of results relative to actual applications is questionable. Therefore, the study of relating musculoskeletal conditions of farmers to disabilities of the CP population, and development of AT for dual-population use, is expected to also yield substantial contributions for the CP scientific community. This study focused on the LE, as both farmers and CP patients most commonly report pain in these body parts. Figure 1 illustrates an example of rice farmer posture during the planting process as compared with the posture of a CP patient in standing. A rough similarity in leg position can be observed.

(a) (b)

Fig. 1 Example of posture comparison between: **a** farmer in planting activity; and **b** CP patient in standing

2 Methodology

2.1 Participants

Four CP patients (1 male and 3 female with age 15.5 ± 2.4 years) with spastic diplegia were recruited from the Srisangvalya Khon Kaen School for children with special needs. Access to CP patients through hospitals, clinics or educational facilities is extremely limited in both Thailand and the U.S. We were able to access a limited sample through contacts at the Khon Kaen University School of Medicine. Spastic diplegia was selected since this form of CP exhibits significant and constant tightness and stiffness in LE muscles. All CP patients who participated in this study had no surgeries on their spine and LE within 12 months prior to enrollment in the study. Participants also had LE pain that was related to foot mechanics.

2.2 Examination of LE Malalignments

The LE malalignment examination was conducted with CP participants to compare structural abnormalities with rice farmers. Anatomical alignment characteristics were measured for each participant, including pelvic angle, femoral antetorsion, quadriceps (Q) angle, tibiofemoral angle, genu recurvatum, tibial torsion, rearfoot angle, and medial longitudinal arch angle. All measurements were repeated three times by a single examiner with excellent test-retest reliability on all LE measures (ICC range of 0.89–0.98). The same examiner also performed the LE alignment examinations of rice farmers in our previous study. Participants were asked to be clothed in shorts that exposed LE parts for testing. For all standing measurements, participants were asked to stand barefoot with feet positioned at biacromial width and toes pointing forward. The procedure of the LE alignment measurements and classifications followed guidelines from the literature, similar to those used in our previous study [7]. Descriptive statistics were used to summarize all participant alignment characteristics.

2.3 Analysis of LE Pain Perception

Investigation of LE pain, as perceived by CP patients, was conducted for comparison with LE pain previously rated by rice farmers. The rice farmers were asked to fill out the Thai version of the Standardized Nordic Questionnaire (SNQ; [12]) for LE discomfort assessment before and after each stage of a complete cultivation cycle. Pain rating scales ranged from 0 to 10 points, where 0 represents no pain and 10 was intolerable pain. However, the self-report SNQ was not appropriate for use with CP patients due to participant inability to comprehend questions and perform quantitative judgments [13]. Therefore, investigators interviewed CP participants and asked for verbal assessment of the level of LE pain they perceived during daily living activities. The investigators translated participant expressions of pain into rating numbers based on guidelines from the Borg CR10 Scale [14].

2.4 Examination of Structural Origin of LE Pain

Physical examinations were conducted to identify the origin of symptoms and affected structures of CP patients for comparison with rice farmer physical exam results. The structural origins of LE pain were identified for each of the 4 CP participants. The examinations of farmers were previously conducted after the target planting process. Examinations were two-stage including: functional screening and diagnostic testing. The procedure of the LE physical examination followed guidelines from the literature [15–19]. The screening examinations included: small knee bend (SKB); single dominant leg SKB; lunge; hop lunge and step-down [15]. A positive screening result was indicated if limited motion occurred or LE pain was perceived in comparison to the contralateral side. The diagnostic portion of the exam was conducted to detect the pathology for the intra-articular LE joint and was performed using a passive physiological movement [16]. LE muscle injury was also measured by a palpation test using pressure pain threshold resistance, an isometric contraction test and muscle length test [17, 18]. A positive result for at least one of the three examinations indicated LE muscle impairment. Neural tissue impairments were also assessed by prone knee bending, Straight Leg Raise (SLR) or slump test [18, 19]. A positive result for one of these three examinations indicated a neural tissue impairment.

All examinations were conducted by a single examiner, who is an expert physical therapist with 10 years of clinical experience in assessing MSDs and achieved very high test-retest reliability in all testing (ICC ≥ 0.9). This examiner also performed the LE diagnostic tests on rice farmers in our previous study. Descriptive statistics were used to analyze characteristics of the LE musculoskeletal impairment variables.

3 Results

3.1 Comparison of LE Malalignments

The average of three LE alignment measurements was used for analysis purposes. Table 1 presents the prevalence of LE malalignments for both rice farmers and CP participants, as observed in our previous and present studies. The findings indicated that foot and knee malalignments are common among Thai rice farmers as well as

Table 1 Prevalence of lower extremity malalignment

Characteristics	Malalignment (%)	
	Rice farmers	CP patients
Anterior pelvic tilt	10.96	0
Excessive femoral antetorsion	6.85	75
Knee valgus	18.49	100
Knee varus	3.43	0
Knee hyperextension	5.82	0
External tibial torsion	11.64	75
Foot pronation	20.89	100

CP patients. The prevalence of LE malalignments of rice farmers was greatest for foot pronation (20.89 %), followed by knee valgus (18.49 %). In line with results of the farmer investigation, all CP participants also exhibited foot pronation and knee valgus. No posterior pelvic tilt or supinated foot conditions were observed in either population.

3.2 Comparison of LE Pain Perception

Mean and standard deviation of perceived pain ratings for each LE body part for CP participants and rice farmers (induced by the planting task performance) are in Table 2. Pain rating results indicated farmers perceived the greatest pain at the hips and knees. During planting activities, farmer work posture is typically a combination of squatting, bending forward, and rotation of the trunk for several hours per work shift. Similarly, CP patients also perceived more pain in the hips and knees during daily living activities.

3.3 Comparison of Structural Origin of LE Pain

The prevalence of LE impairment-related pain characteristics of rice farmers and CP patients are in Table 3. Physical examinations, including functional and diagnostic tests, indicated that the origins of pain in farmers were due to impairments of

Table 2 Perceived pain ratings of LE body parts for rice farmers (resulting from planting task performance) and CP patients

Body part	Perceived pain ratings (mean ± SD; 0–10 score range)	
	Rice farmers	CP patients
Hip	6.08 ± 3.98	6.00 ± 1.83
Knee	3.55 ± 3.08	6.00 ± 1.83
Ankle/foot	0.52 ± 1.66	3.25 ± 3.95

Table 3 Prevalence of LE impairment-related pain characteristics of rice farmers and CP patients

Origin of pain	Musculoskeletal impairment (%)	
	Rice farmers	CP patients
Joint		
• Hip	22.18	0
• Knee	54.61	100
• Ankle and foot	5.12	100
Muscle		
• Hamstring	36.18	100
• Quadriceps	30.38	0
• Gastrocnemius	26.28	100
Neural tissue	26.62	0

the knee joints (54.61 %) and LE muscles [hamstring (36.18 %), quadriceps (30.38 %), and gastrocnemius (26.28 %)]. Partially conforming with farmer examination results, CP participant physical exams indicated origins of pain included impairments of the knee and ankle joints. The structural origin of pain for CP participants was also the hamstring and gastrocnemius muscles, but not the quadriceps muscle. Taken together, our results showed similar origins of pain for both populations.

4 Discussion and Conclusion

This research attempted to relate pain and work-related disabilities of the LE in rice farmers to the disability characteristics of a non-occupational population, specifically CP patients, as a basis for supporting dual-use AT designs for patients in daily living activities as well as farmers in work tasks. The musculoskeletal and disability conditions of the two populations were mapped to each other in terms of symptoms (malalignment and pain perception) and causes (origin of structural damage).

The comparison of farmers and CP participants showed that both populations are related in terms of knee valgus prevalence, knee pain perception, and knee musculoskeletal impairments. Therefore, knee impairments and MSDs should be emphasized in the development of any dual-use AT designs in order to prevent further risk of LE injury for both farmer and CP populations. The overall research findings are illustrated in Fig. 2.

In general, there is a need for disability engineering research to develop efficient and effective methods for characterizing disabling physical conditions of non-occupational populations due to genetic or disease factors as well as those of occupational populations due to work environment conditions and/or injury. This research can be used as a basis for designing dual-use AT for CP patients with loss of muscle control due to neurological dysfunction and in farmers due to work environment conditions.

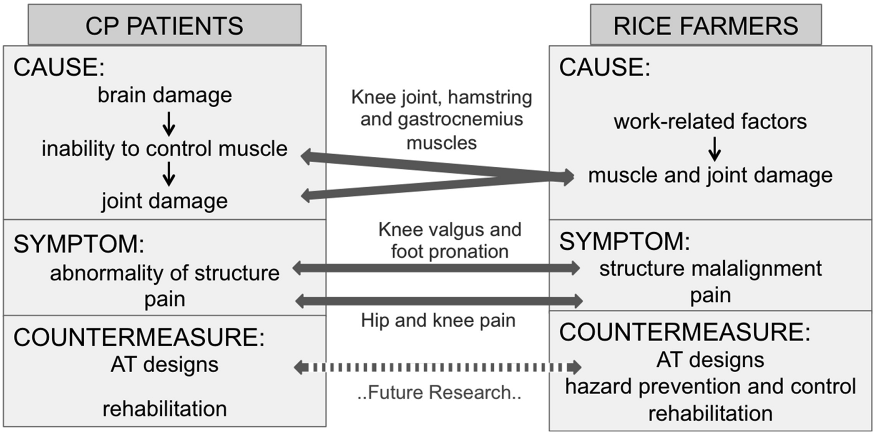

Fig. 2 Overall findings in the study

This research provided a preliminarily mapping of occupation-related MSDs to congenital disabilities of CP patients. In our previous study, we examined a substantial number of rice farmers to ensure reliability of our results. In the present work, we studied a limited number of CP patients due to access issues. Despite this limitation, we were able to make comparisons of physiological conditions among the two populations. Another limitation of the study included different assessment methodology used for rice farmers and CP participants (SNQ vs. Borg CR10). Due to inability to comprehend questions of CP participants, investigators had to interpret and translate participant expressions of pain into rating numbers of Borg CR10 scale. This might lead to an inaccuracy in the pain perception results of CP patients. Moreover, although we avoided using Likert self-report questionnaire, the interview questions still involved judgments of degree, which may be problematic for CP patients. Finlay and Lyons [13] recommended using screening questions regarding concrete events which frequency is known in pretest sessions. Our future study will include the pretest sessions, developed in collaboration with CP patient caretakers, to ensure the correction of such judgments.

Follow-on research is expected to include more CP participants to support inferential statistical analyses on results from the rice farmers and CP patients. Furthermore, we plan to pursue: dual-population AT design; rapid prototyping of low-cost highly usable AT (e.g., foot and knee orthotics); performance assessment using ergonomic measurement methods; and design validation using high-fidelity lab mock-ups of farm and daily living tasks as well as actual field tests.

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