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Electrotherapy on tattoo is to be concerned

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Tattoo is a common social trend, and it is getting more popular nowadays. A projected 10% of the adult population in the wider Western world was reported to have at least one tattoo.[1] Recently, these permanent cosmetics are getting medical professionals' curiosity about their chemical/physical properties and their effect on the dermatologic health of patients. Tattoo colorants can be made of different substances including metals such as titanium and aluminum,[2] other materials such as carbon and metallic compounds like iron oxide and lead carbonate are also commonly used in tattoo inks. The common iron oxide-based pigments (usually black and brown) have been shown to be ferromagnetic,[3,4] and they could react with an external magnetic field and become magnetized.

Electrical stimulation and thermal agents are regularly used in physiotherapy for therapeutic purposes. Frequently used modalities such as transcutaneous electrical nerve stimulation (TENS) and neuromuscular electrical stimulation (NMES) are interventions which are applied through patients' skin for physiotherapy treatments. As mentioned above, the ferromagnetic compounds of tattoo pigments can be magnetized while the metallic compounds can possibly induce electric currents.[3] As a result, it is possible that if an electric current is applied on the tattooed skin, the surface temperature will increase unexpectedly and cause a burn. Furthermore, there are already case reports published that tattoo could potentially induce skin burn while taking magnetic resonance imaging (MRI) possibly due to the magnetic-induced electric current on the skin.[3–5]

There have been safety guidelines and contraindications for the application of electrophysical therapy (EPT) on patients.[6] Several conditions such as pacemaker, tumor and pregnancy are well documented for whether they are safe to be included or excluded but not yet for the tattoo. Some latest safety guidelines of healthcare procedures have started to highlight the concern of tattoo.[5] but not yet on EPT. Therefore, there is a necessity to discuss and investigate the safety practice of EPT on patients with tattoo.

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Mobility performance among community-dwelling older Filipinos who lived in urban and rural settings: A preliminary study

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Background: The impact of residential setting on the performance of older adults on commonly used instruments of mobility has not been closely investigated.
Objective: This study aimed to (1) explore whether mobility test performance differed between those who lived in urban and rural communities, and (2) report preliminary reference values for these tests according to residential setting.
Methods: The study used a descriptive design. Individuals who were aged 60 years and above, had no significant disability, and resided in urban and rural areas in the Philippines ($n = 180$), participated in the study. Researchers measured mobility performance using the 10-Meter Walk Test (10MWT) (both comfortable gait velocity (CGV) and fast gait velocity (FGV)), Five Times Sit to Stand Test (FTSST), and

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Six-Minute Walk Test (6MWT). Preliminary reference values for the mobility tests were presented as means, standard deviations, and 95% confidence intervals. Scores were compared based on residential setting (urban versus rural).
Results: Urban-dwellers scored consistently better compared to their rural counterparts on the CGV, FGV, FTSST, and 6MWT using independent samples t-test ($p < 0.001$). Data were further divided according to age and sex, and comparison of the mobility test scores between urban- and rural-dwellers within each subgroup showed similar differences ($p < 0.01$).
Conclusion: Results provide preliminary evidence for the influence of residential setting on the mobility test performance of Filipino older adults. The study provides a good starting point for confirmatory research with a representative sample to (1) illustrate differences in mobility performance according to residential setting, (2) investigate how specific factors associated with residential settings contribute to differences in mobility performance, and (3) determine the extent to which clinicians should consider an older person's residential setting when interpreting mobility test results.

Keywords: Aged; geriatric assessment; mobility limitation; rural population; urban population; walking.

Introduction

Mobility is defined in the International Classification of Functioning, Disability and Health (ICF) as "moving by changing body position or by transferring from one place to another, by carrying, moving or manipulating objects, by walking, running or climbing, and by using various forms of transportation".[1] It is a key component of healthy aging and fundamental to involvement in life situations.[2,3] Frailty and loss of function associated with aging negatively impact mobility and increase risk for injuries and further disability.[4] As a result, frailty can potentially restrict participation and impair quality of life.

A scoping review published in 2015 found that environmental characteristics such as proximity to resources and recreational facilities, social support, public transportation, and neighborhood security are associated with greater mobility in older adults.[5] The review also highlighted that poor user-friendliness of the walking environment and neighborhood insecurity can negatively impact mobility.[5] Such factors may be argued to relate to whether a person lives in a rural or urban setting. Older adults in rural settings have been found to have poorer health compared to their urban-dwelling peers due to greater difficulty in accessing health care and resources.[6] Walking behavior, found to be linked to mobility, also differs since rural-dwelling individuals take less steps per day and engage in less walking compared to urban-dwelling individuals.[7,8] Walkability, which refers to proximity of environmental destinations and the degree to which these are connected through a street network,[9] may also be higher in urban communities compared to rural areas.[8]

Because mobility is multidimensional, its assessment requires a variety of construct-specific instruments that relate to its dimensions (e.g. time constraints, distance, and postural transitions, etc.).[2] These instruments play an important role in diagnosing mobility limitations, aiding prognosis, and measuring progress following intervention.[10] While reference values for these instruments are widely available for interpreting patient scores, most have only considered differences related to age, sex, and ethnicity.[10–13] Little is known if such reference values are influenced by residential setting. One study compared functional performance between urban- and rural-dwelling older people using the 7-item Physical Performance Test, an objective measure that includes mobility-related items (i.e., walking and turning).[14] However, only cumulative scores representing overall physical function were reported, thus limiting usefulness as reference data for mobility-specific performance.

This study primarily aimed to explore whether the performance of Filipino older adults on commonly used mobility-specific assessment instruments differed based on residential setting. The secondary aim is to report preliminary reference values according to residential setting. This

knowledge will eventually aid clinicians in assessing and interpreting mobility-specific assessment instruments.

Methods

This study used a descriptive design. The Ethical Review Committee of the University of the Philippines Manila — College of Allied Medical Professions approved the research protocol. All participants provided written informed consent.

Participants

Volunteers from urban areas in the National Capital Region and rural areas in southern provinces of the Luzon island in the Philippines participated in the study. Participants were sourced through public announcements, active recruitment from various senior citizen communities, church and leisure groups, and the researchers' networks. The inclusion and exclusion criteria detailed in Table 1 guided participant recruitment.

Target sample size was calculated using 10-Meter Walk Test (10MWT), comprising comfortable gait velocity (CGV) and fast gait velocity (FGV), as the main assessment instrument of interest. The hypothesized mean difference between urban- and rural-dwelling older adults was based on reference values from the existing literature.[11,13] Within-group standard deviation was set to 0.2, desired significance level to 0.05, and power to 0.8. For CGV, the hypothesized true mean difference was 0.1 m/s, and the approximate sample size required per group for this was 64 urban- and rural-dwelling older adults. For FGV, the hypothesized true mean difference was 0.23 m/s and the approximate sample size per group was 13.

Tests and procedures

Data were collected from October 2011 to October 2012. Researchers gathered demographic and health-related information from volunteers through individual interviews to screen for eligibility. Height and weight were measured using a wall-mounted measuring tape and a calibrated weighing scale, respectively. Performance on standardized mobility tests were assessed in the following order to minimize fatigue: 10MWT, Five Times Sit to Stand Test (FTSST), and Six-Minute Walk Test (6MWT). For the 10MWT, researchers tested for CGV first, followed by FGV. Participants underwent two test trials for the FTSST and 10MWT after one demonstration from the researchers and a practice trial. Researchers recorded each participant's average score from the two test trials for each test for data analysis. For the 6MWT, researchers implemented a modified practice trial by asking participants to do one round on the walking course to minimize fatigue. Participants then underwent one test trial for the 6MWT, with the researchers recording the scores from this trial for data analysis. Participants wore comfortable clothing and their usual footwear.

The 10MWT was selected as the primary assessment instrument as it is considered a predictor of mobility disability, mortality, and function in older adults.[15] The test determines a person's gait velocity which can provide information on ability to perform time-constrained tasks encountered in community mobility.[2] Testing for CGV has high to very high test–retest reliability in older adults (ICC = 0.78–0.94)[16] and interrater reliability among individuals with stroke (ICC = 0.98).[17] Testing for FGV has good test-retest (ICC = 0.81–0.99) and inter rater reliability (ICC = 0.87–0.99) among individuals with neurologic conditions.[18] CGV predicts mobility decline in older adults

Table 1. Inclusion and exclusion criteria.

Inclusion criteria	Exclusion criteria
• aged 60 years and higher • able to walk outdoors without need for physical assistance or supervision • able to walk for at least six minutes without experiencing shortness of breath or pain • able to follow simple instructions in English or Filipino • able to provide informed consent	• required an assistive device in standing or walking • had uncorrected visual impairment • had any significant or uncontrolled neurologic, cardiopulmonary, or musculoskeletal condition known to affect balance and mobility (including surgery, chemotherapy, or radiation therapy within the previous six months; acute illness or injury at the time of testing; history of loss of consciousness or falling within the previous three months)

(relative risk = 2.98).[16] FGV has been moderately associated with the Timed Up and Go (TUG) test, a widely-used measure of mobility in older adults ($r = -0.67$).[19] Researchers administered the 10MWT by instructing participants to walk over a 10-meter level walkway, at a usual or comfortable speed for CGV and as fast as possible without running or losing balance for FGV.[10] Using a stopwatch and while walking with the participant, the rater started the timer as soon as a foot of the participant crossed the second-meter mark and ended it after the foot passed the eighth-meter mark. Thus, the testing protocol recorded the middle six meters of the 10-meter walkway. The reason for the use of this procedure was to facilitate comparison with protocols used in reference values for the 10MWT.[10,11]

The FTSST, while conventionally used to evaluate an older adult's functional lower extremity strength and dynamic balance,[20,21] also measures mobility as defined in the ICF because it involves transition from a seated position into a standing position and vice versa.[1] Among older adults, the test has excellent test-retest reliability (ICC = 0.89)[22] and correlation with the TUG ($r = 0.64$).[23] Researchers obtained scores on the FTSST by recording the time in seconds taken by the participants to stand up five times from a chair as fast as possible with arms folded across the chest.[24] Timing started as soon as the participant's buttocks were lifted off the chair and ended upon contact during the fifth repetition.[22,25] A chair that allowed approximately 90 degrees of hip and knee flexion was used for the test.

The 6MWT assesses the farthest distance an individual can traverse in six minutes while providing information on the interaction of musculoskeletal, cardiovascular, and neurologic systems.[26] The test has excellent test-retest reliability (ICC = 0.94–0.96),[10] and concurrent validity with chair stands ($r = 0.67$), standing balance ($r = 0.52$), and gait speed ($r = -0.73$)[26] in older adults. Application of the 6MWT adhered to the guidelines of the American Thoracic Society, in which a straight 20-meter level-surface walkway was used to measure distance covered at a self-selected pace continuously for six minutes.[27]

Data analysis

Researchers used SPSS 20 for Windows (IBM Corporation, Armonk, NY, USA) for statistical analysis. Data were analyzed based on residential setting (urban versus rural). Overall, mobility test scores followed a normal distribution (Kolmogorov–Smirnov test, $p > 0.05$) and therefore means, standard deviations, and 95% confidence intervals were reported. Levene's test revealed generally equal variance across all datasets ($p > 0.05$). Thus, mobility test performance between urban and rural groups was compared using an independent samples t-test, with significance level set at 0.05. For data to be clinically useful and to facilitate comparisons with existing reference values, age- and sex-related descriptive data were reported as well. Age brackets by decade similar to existing studies on reference values for mobility tests were used.[10,13,21] Each age group was further divided to subgroups according to residential setting (i.e., 60–69 rural, 60–69 urban, 70–79 rural, and 70–79 urban) and mobility performance of rural- and urban-dwellers within the same age group was compared using an independent samples t-test. Similar subgroups were formed and compared based on biological sex and residential setting (i.e., male urban, male rural, and female urban, and female rural). All the subgroups followed a normal distribution based on visual inspection and the Shapiro–Wilk test ($p \geq 0.05$).

RESULTS

A total of 180 Filipino older adults participated in the study. Demographic characteristics are

Table 2. Participant demographic data.

	Entire sample ($n = 180$)		Rural ($n = 55$)		Urban ($n = 125$)	
Variable	Mean (SD)	95% CI	Mean (SD)	95% CI	Mean (SD)	95% CI
Age (year)	67.58 (5.41)	66.78–68.37	67.16 (5.30)	65.73–68.60	67.76 (5.46)	66.79–68.73
Height (cm)	155.85 (10.45)	154.31–157.39	157.56 (7.57)	155.71–159.80	155.01 (11.42)	152.99–157.03
Weight (kg)	53.18 (10.58)	51.63–54.74	53.10 (7.85)	50.98–55.22	53.22 (11.60)	51.17–55.28
Body mass index	21.87 (3.89)	21.3–22.44	21.30 (1.87)	20.80–21.81	22.12 (4.49)	21.33–22.92

Table 3. Participant scores according to residential setting.

	Entire sample ($n = 180$)		Rural ($n = 55$)		Urban ($n = 125$)		Rural versus urban comparison (t-test p-value)
	Mean (SD)	95% CI	Mean (SD)	95% CI	Mean (SD)	95% CI	
FTSST	9.29 (2.64)	8.90–9.68	11.06 (2.57)	10.36–11.75	8.51 (2.27)	8.11–8.92	<0.001
6MWT	409.8 (96.0)	395.7–423.9	303.1 (54.4)	288.4–317.8	456.7 (69.0)	444.5–468.9	<0.001
CGV	1.17 (0.21)	1.14–1.20	1.01 (0.12)	0.98–1.04	1.23 (0.20)	1.20–1.27	<0.001
FGV	1.50 (0.27)	1.46–1.53	1.34 (0.21)	1.28–1.39	1.57 (0.26)	1.52–1.61	<0.001

Notes: CGV = Comfortable gait velocity; CI = Confidence Interval; FGV = Fast gait velocity; FTSST = Five Times Sit to Stand Test; SD = Standard Deviation; 6MWT = Six-Minute Walk Test.

presented in Table 2. The sample comprised a larger proportion of female participants (60%, 108/180) and urban-dwellers (69%, 125/180). Mean age of participants was 67.58 ± 5.41 years.

Mobility test performance is summarized for all participants and is according to residential setting in Table 3. Urban-dwellers demonstrated consistently higher scores compared to their rural-dwelling counterparts on the 10MWT (both CGV and FGV), FTSST, and 6MWT ($p < 0.001$). The differences were observed even when values were presented according to age (Table 4) and sex (Table 5) ($p < 0.01$). Those living in urban areas consistently walked faster for both CGV and FGV, had faster (lower) FTSST times, and covered farther distances on the 6MWT compared to their rural counterparts.

Discussion

Findings suggest a consistent pattern of higher performance across mobility-specific assessment instruments among urban-dwellers compared to rural-dwellers. To our knowledge, this is the first study that compared mobility-specific test scores between urban- and rural-dwelling older adults. Thus, direct comparison of findings to existing literature is limited. However, overall findings relate with those of a probability study that found higher functional status among urban-dwelling compared to rural-dwelling Filipinos on the 7-item Physical Performance Test.[14] As highlighted in the literature, proximity to resources and recreational facilities, social support, public transportation, and neighborhood security positively impact mobility of older adults.[5] On the other hand, poor user-friendliness of the walking environment and neighborhood insecurity limit mobility.[5] Rural areas in the Philippines, being generally less-developed compared to urban areas, offer limited key walking destinations such as public transits, neighborhood shops, and services. Walking routes may also be perceived as less safe because of inadequate street lighting and traffic control. All of these have been linked to less walking activity[28] and likely impact on mobility in a negative way. Differences in social roles between older adult cohorts in different residential settings should also be considered, for example among women in rural areas who often engage in caregiver/home management duties. Such responsibilities have been found to be a barrier for leisure-time physical activity[29] and thus may negatively affect physical performance.

When preliminary reference values were presented according to age- and sex-based subgroups, the pattern of higher mobility test scores among urban-dwellers compared to rural-dwellers was still consistently observed. Further division of the data into subgroups allowed comparison with existing reference values. Overall, mobility performance of the rural-dwelling participants on the 10MWT (both CGV and FGV) and 6MWT aligns with the reference values obtained from rural-dwelling South East Asian and North East Asian cohorts.[11,13] Aoyagi *et al.* obtained CGV and FGV from 151 rural-dwelling Japanese older adults, although only women were recruited in their study.[11] Thaweewannakij *et al.* recruited most of the 1030 well-functioning older adults in their study from rural and semi-rural communities in Thailand (Thaweewannakij T, PhD, 2014, e-mail communication, 15th August). In comparison, mobility performance of urban-dwelling participants on the CGV and FGV was similar to that of 604 urban-dwellers in the same study involving Japanese older women by Aoyagi *et al.*[11] Interestingly, the means and confidence intervals of the urban-dwelling participants' 10MWT and 6MWT scores were closer to the reference values reported for

Table 4. Age-related reference values according to residential setting.

	60–69 years				Rural versus urban comparison within 60–69 age group (t-test p-value)	70–79 years				Rural versus urban comparison within 70–79 age group (t-test p-value)
	Rural ($n = 37$; females = 25 (68%))		Urban ($n = 80$; females = 45 (56%))			Rural ($n = 18$; females = 15 (83%))		Urban ($n = 45$; females = 23(51%))		
	Mean (SD)	95% CI	Mean (SD)	95% CI		Mean (SD)	95% CI	Mean (SD)	95% CI	
FTSST	11.18 (2.48)	10.35–12.01	8.30 (2.22)	7.81–8.80	<0.001	10.80 (2.79)	9.41–12.19	8.89 (2.34)	8.18–9.59	0.007
6MWT	313.22 (53.04)	295.54–330.90	465.93 (61.23)	452.30–479.55	<0.001	282.40 (52.50)	256.29–308.51	440.29 (78.98)	416.56–464.02	<0.001
CGV	1.03 (0.13)	0.96–1.08	1.24 (0.18)	1.20–1.28	<0.001	0.96 (0.11)	0.91–1.02	1.22 (0.23)	1.15–1.29	<0.001
FGV	1.40 (0.22)	1.32–1.47	1.59 (0.24)	1.54–1.64	<0.001	1.21 (0.14)	1.14–1.28	1.52 (0.29)	1.43–1.61	<0.001

Notes: CGV = Comfortable gait velocity; CI = Confidence Interval; FGV = Fast gait velocity; FTSST = Five Times Sit to Stand Test; SD = Standard Deviation; 6MWT = Six-Minute Walk Test.

Table 5. Sex-related reference values according to residential setting.

	Male				Rural versus urban comparison within male group (t-test p-value)	Female				Rural versus urban comparison within female group (t-test p-value)
	Rural ($n = 15$; mean age = 66 ± 5.78)		Urban ($n = 57$; mean age = 67.60 ± 5.58)			Rural ($n = 40$; mean age = 67.6 ± 5.11)		Urban ($n = 68$; mean age = 67.90 ± 5.40)		
	Mean (SD)	95% CI	Mean (SD)	95% CI		Mean (SD)	95% CI	Mean (SD)	95% CI	
FTSST	12.01 (2.23)	10.78–13.25	7.71 (1.88)	7.21–8.21	<0.001	10.70 (2.62)	9.86–11.54	9.19 (2.34)	8.62–9.76	0.003
6MWT	327.58 (47.76)	301.13–354.02	491.12 (63.12)	474.37–507.86	<0.001	293.97 (54.39)	276.57–311.36	427.85 (60.15)	413.29–442.41	<0.001
CGV	1.08 (0.12)	1.01–1.14	1.23 (0.19)	1.25–1.35	<0.001	0.99 (0.12)	0.95–1.03	1.18 (0.19)	1.13–1.22	<0.001
FGV	1.49 (0.21)	1.38–1.61	1.72 (0.24)	1.65–1.78	0.002	1.28 (0.19)	1.22–1.33	1.44 (0.20)	1.39–1.49	<0.001

Notes: CGV = Comfortable gait velocity; CI = Confidence Interval; FGV = Fast gait velocity; FTSST = Five Times Sit to Stand Test; SD = Standard Deviation; 6MWT = Six-Minute Walk Test.

Caucasian cohorts than for the Thai cohort.[10,13,21,30] However, it was unclear from which residential setting the Caucasian cohorts had been recruited.[10,21,30] These patterns in mobility performance on the 10MWT and 6MWT support the hypothesis that residential setting may be an influencing factor in the mobility performance of community-dwelling older adults.

Urban-dwellers in the present study had similar FTSST scores to the urban-dwelling Japanese women in the study by Aoyagi *et al.*, although they found that the scores of urban- and rural-dwelling Japanese older women on the FTSST were not different.[11] An important factor that might have contributed to their observation would be the Japanese culture of squatting which had been linked to better sit-to-stand performance.[11] FTSST scores from rural-dwellers in this study were similar to those reported by Thaweewannakij *et al.* for rural- and semi-rural-dwelling Thai older adults, and by Bohannon in a meta-analysis of study results obtained mostly from American older adults.[13,20] While similarity of scores with the Thai cohort may be attributed to similarities in participant characteristics, it would be difficult to elucidate the similarities with the findings of the meta-analysis because residential setting was not specified in most of the included studies.[20]

The study results serve as a good foundation for confirmatory research that can provide a more precise picture of the extent to which mobility test performance differs according to residential setting. Results also provide a basis for studies that will clarify the need to consider residential setting in addition to the already-established age, sex, and ethnical (i.e., anthropometric) factors. Clinicians may then acquire a better understanding of mobility in older adults and more accurate interpretation of scores on mobility assessment instruments. It would also be worthwhile to investigate whether a similar extent of rural–urban difference exists in different regions in consideration of inter-region differences in socio-cultural and environmental characteristics. Should future research confirm residential setting as a critical factor in interpreting mobility test scores, population-specific reference values must be revisited as well. In developing countries, a larger population of older adults live in rural communities than in urban communities, while the opposite has been observed in more developed areas.[31] Existing reference values that were obtained from majorly urban or rural samples or were from studies that did not report residential setting may need to be used with caution when making clinical judgments regarding the mobility of older people.

Lastly, the impact of environmental, socio-cultural, and health-related factors on mobility could not be confirmed in this preliminary investigation since it was beyond the objectives. Therefore, future research should endeavor to clarify whether some of these factors (e.g., specific environmental characteristics, social roles and level of physical activity) can explain why mobility test performance differs among older adults in urban and rural communities. Factors associated with residential setting that relate to better or worse normative performance on mobility tests may also be identified through further research. Such studies can widen clinicians' perspectives of the range of mobility test performance that constitutes normal mobility in community-dwelling older adults.

Careful consideration of the study limitations is required when interpreting the study results. Due to the convenient nature of sampling and relatively small sample size, findings of this study may be a preliminary representation only of how urban- and rural-dwelling older persons comparatively perform on the mobility tests. While the sample size for urban-dwelling participants met the projections for CGV and FGV, the sample size for the rural-dwelling group met the projection for FGV only. Fewer participants aged 70–79 were also recruited. It should be noted too that the testing methods for the 10MWT and FTSST in this study aligned with some published studies and differed from others in the literature. This study's protocol for the 10MWT involved measuring time over the middle six meters of the 10-meter walkway, similar to previous studies reporting reference data for mobility-specific tests for older adults.[10,11] However, future studies may consider measuring time over the middle four meters of the walkway instead, similar to the methodology used by Thaweewannakij *et al.*, to factor in acceleration and deceleration effects that may take up to three meters.[13,32] The method for timing the FTSST in this study was consistent with previous studies,[22,25] while other studies used a different methodology[13] or did not provide sufficient details to allow comparison.[11,21] Such methodological differences must be considered when using data from different studies. Future studies should use a uniform testing protocol to facilitate comparison across studies. Lastly,

because participants were recruited from the Philippines, the patterns observed in the mobility test performance of this cohort may not necessarily be generalizable to other countries that do not share similar characteristics of rural–urban settings with the Philippines.

In conclusion, this study provides preliminary evidence on the influence residential setting on mobility test performance of older adults. The study is useful in generating a hypothesis regarding mobility performance differences between urban- and rural-dwelling older adults. However, future research should test the hypothesis using an appropriate research design and sample size. This study also highlights the importance of examining further what underpins the differences in mobility performance among older adults based on residential setting. Results of the study serve as a good starting point for a series of studies that will lead to a better understanding of how environmental, socio-cultural, and health-related factors influence mobility among older adults.

Conflict of Interest

The authors have no conflict of interest relevant to this paper.

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Author Contributions

E. J. Gorgon was responsible for conception and design of the study. F. R. Lunar and E. J. Gorgon were involved with analysis/interpretation of data, and critical revision of the manuscript for important intellectual content. All authors were involved in acquisition of data, drafting the manuscript, and approval of the manuscript to be published.

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Athletes' expectations about physiotherapy in sports injury rehabilitation in greater Accra region

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Background: Physiotherapists play a key role in sports injury rehabilitation within the sports healthcare team. A strong athlete–physiotherapist relationship is necessary for effective treatment and shaping of athletes' expectations of injury rehabilitation. Hence, it is necessary to factor the injured athletes' expectations in structuring a rehabilitation program.
Objective: The aim of this study was to determine athletes' expectations about physiotherapy in sports injury rehabilitation.
Methods: We performed a cross-sectional survey in which data was collected using the expectation about athletic training (EAAT) questionnaire from 120 recruited athletes of different sporting disciplines. Percentages, means and standard deviations of the expectation scores were computed. Associations between socio-demographic characteristics and athletes' expectations of physiotherapy in sports injury rehabilitation were analyzed with the chi-square test. Differences between the athletes' expectations of physiotherapy and

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demographic characteristics were also analyzed with Kruskal–Wallis and Mann–Whitney tests.
Results: The study revealed that there was no significant difference ($p > 0.05$) between gender, injury type, physiotherapy experience and mental skills experience and the athletes' expectations. There was a significant difference ($p < 0.05$) between competition level and athletes' expectations.
Conclusion: It was concluded that athletes in the Greater Accra Region have high expectations of physiotherapy in injury rehabilitation; thus sports physiotherapists would need to enhance their communication with athletes which may also help them better understand the risks, benefits, timeline and rehabilitation approach.

Keywords: Expectation; physiotherapy; sports injury; rehabilitation.

Introduction

Sports injuries occur while participating in organized sports, competitions, training sessions or organized fitness activities.[1] Common high-injury risk sports are football or soccer, basketball, cricket, volleyball, skiing and tennis.[2] Sports injuries result from acute trauma or repetitive stress associated with athletic activities; and can affect bones, soft tissues (ligaments, muscles and tendons) or other organs like the heart, lungs and eyes.[3] Sports-related injuries can be grouped into sprains, strains, fractures, concussions as well as spinal cord, internal organ and head injuries.[3] The importance of psychological factors in sports injury rehabilitation has grown over the past four decades.[4] A study in 2009 proposed that physiotherapists should use a much more holistic approach and incorporate psychological components within their rehabilitation program.[5]

Roughly one out of every 100,000 American high-school athletes sustained a certain form of catastrophic injury.[6] Among collegiate athletes, the injury rate for direct and indirect catastrophic sports injuries was 3.86 per 100,000 participants.[6] The epidemiology of soccer injuries in Rwanda revealed that injury prevalence was 68.1% and the most affected body parts were the ankle and knee.[7] It is obvious that injuries are a likely part of an athlete's life.

The fear of re-injury causes an athlete to hold back, hesitate, heavily tape the injured area and not give 100% effort in an attempt to be cautious and not cause a re-injury.[8] Rehabilitation of sports injuries involves more than just repairing the physical injury and regaining previous levels of physical performance, like understanding the impact of the injury on the athlete and how the psychological factors may interact with the rehabilitation process.[9] The primary aim of physiotherapy in injury rehabilitation is to treat and fully rehabilitate the athlete post-injury or post-operation to prevent further injury and to make the athlete return to the sport within the shortest possible time.[10] Washington-Lofgren *et al.*[11] revealed that athletes expect physiotherapists to provide them with informational support and this helps to shape their expectations of injury rehabilitation. Moreover, athletes have also expressed high expectations from their physiotherapists, believing they (physiotherapists) are capable of recognizing and fulfilling their motivational needs and understanding. This emphasizes the need for physiotherapists to become aware of such athletes' expectations and the need to acquire additional expertise that allows them to meet these expectations. Athletes with positive expectations towards returning to sport have a reduced risk of re-injury as compared to athletes with negative expectations.[1] Lee[10] revealed that athletes have high expectations for accurate informational support and expertise from the physiotherapist. The athletes had expectations for directiveness, genuineness and openness in anticipating information and guidance from the physiotherapist and in setting rehabilitation goals.[10] They also had moderate expectations to be personally committed towards their rehabilitation process.[10] However, the influence of personal and situational factors on an athlete's response to injury and rehabilitation appears inconclusive. Dowswell *et al.*[12] reported that patients' outcomes of dissatisfaction in physiotherapy (treatment or recovery) have been, in part, attributed to unrealistic expectations. Thus, strong social support from physiotherapists has also been found to help athletes adopt a more positive outlook on their way to recovery, which might be apparent in their strong belief in the rehabilitation process.[8] In addition, clarifying

expectations is important in rehabilitation since it helps athletes reduce uncertainties and anxieties of the unknown by increasing their sense of control.[11]

Sports injury affects the physical, social, emotional, spiritual and financial aspects of the athlete's wellbeing.[13] It therefore becomes imperative to include injury severity as an essential measurement that provides an understanding of the extent to which sports injuries affect an athlete's health. Different aspects are used to determine the severity of sports injuries such as nature of injury, duration, medical attention, sports time loss, working time loss, permanent damage and costs of sports injuries.[14] Despite the nature and anatomical location, the extent of symptoms and other consequences of an injury are also crucial.

A strong athlete–physiotherapist relationship is necessary for effective treatment and shaping of athletes' expectations of injury rehabilitation.[10] Previous studies investigating sports physiotherapy in Ghana have focused mainly on the injury pattern, management of the injuries and the need to use physiotherapy services by athletic teams. There appears to be a dearth of information on the assessment of athletes' expectations about physiotherapy in sports injury rehabilitation in Ghana and hence it became the focus of this study.

Method

A cross-sectional survey was carried out at the University of Ghana, Thodosia Okoh hockey pitch and Accra sports stadium training grounds of the athletes recruited for the study. The participants of the study included active athletes drawn from football (soccer), hockey, basketball, boxing and athletes who had either received physiotherapy services or not. Athletes who could not read and write were excluded from the study. Ethics approval (Appendix A) was sought and obtained from the Ethics and Protocol Review Committee of the School of Biomedical and Allied Health Sciences, College of Health Sciences, University of Ghana, before the commencement of the research (Ethics Approval No. SAHS-ET/1027/3367/AA/26A/2012-2013). Permission was sought and obtained from the Authorities of the different sporting disciplines that were visited. Written consent was also obtained from the athletes who agreed to participate in the study after the rationale of the study had been explained to them. Participants were also assured of anonymity and confidentiality of information obtained.

Data collecting tool

The expectation about athletic training (EAAT) questionnaire used by Lee[10] (Appendix C) was adopted together with a data capturing form (Appendix B) and used to obtain data for this study. The data capturing form was used to capture demographic characteristics such as gender, age, highest educational qualification and level of competition. The EAAT questionnaire assessed the athletes' expectations about physiotherapy in sports injury rehabilitation. Respondents were asked to rate their expectations on a seven-point Likert scale (from 1 = strongly disagree to 7 = strongly agree). Response options "disagree", "moderately disagree", "neutral", "moderately agree" and "agree" were assigned the scores of 2, 3, 4, 5 and 6, respectively.

The EAAT questionnaire comprises 66 items, which measures 11 subscales of athletes' expectations; that is, motivation, openness, responsibility, attractiveness, outcome, acceptance, confrontation, genuineness, nurturance, directiveness and empathy. The questionnaire also considers major dimensions of what athletes may expect when receiving physiotherapy treatment or counseling and also a comprehensive definition of the athletes' expectations in the physiotherapy service delivery. The questionnaire has an internal reliability of 0.79.

Procedure for data collection

Permission to conduct the study was sought and obtained from the managements of the various athletic teams (football, hockey, basketball, boxing and athletics) involved. Participants residing in the Greater Accra Region of Ghana were recruited at the training grounds during their training sessions. Football (soccer) and basketball players were recruited from the University of Ghana, boxers and athletics from the Accra sports stadium and hockey players from the Thodosia Okoh hockey pitch training grounds, respectively.

The data capturing form and questionnaire (Appendices B and C) were distributed to the athletes of the participating sporting disciplines. Some participants completed them after the

training and returned them on the same day. Those who could not complete the form and questionnaire were allowed to take them home and return the completed ones on their next training day. Phone numbers were collected from those who could not complete the questionnaire instantly and follow-ups were made. The researchers collected the data over a two-month period.

Data analysis

The data obtained was analyzed using the SPSS package 18.0. Percentages, means and standard deviations (SDs) of the expectation scores were computed. Kruskal–Wallis test was used to determine the differences in the subscales of athletes' expectations according to competition level and injury type while Mann–Whitney test was used to determine the differences in the subscales of athletes' expectations according to gender, previous experience of physiotherapy and previous use of mental skills training in rehabilitation. The level of significance was set at $p < 0.05$.

Results

The 120 respondents (athletes) recruited for this study comprised of 85 males (70.8%) and 35 females (29.2%). This comprised of 40 footballers (33.3%), 33 hockey players (27.5%), 10 boxers (8.3%), 23 from athletics (19.2%) and 14 basketball players (11.7%). The minimum and maximum ages of the athletes were 18 years and 36 years, respectively, with an average age of 22.5 ± 3.6 years. Table 1 shows the distributions of the socio-demographic characteristics of athletes. Majority of the athletes (39; 32.5%) have been involved in their various sports for over 4–6 years while six athletes (5%) train for over 10–12 h per week.

Figure 1 shows the percentage distribution of sports-related injuries with 43 athletes (35.8%) sustaining single injury and two athletes (1.7%) sustaining eight injuries. The distribution of types of injuries revealed that 90 athletes (75%) had acute injuries, 11 (9%) had chronic injuries and 19 (16%) had both. The results revealed that 80 athletes (66.7%) had minor, 33 (27.5%) had moderate, six (5%) had severe and one (0.8%) had catastrophic types of injuries. Approximately 69 athletes (57.5%) had no previous physiotherapy experience in injury rehabilitation while 51 athletes (42.5%) had had previous physiotherapy treatment in their injury rehabilitation.

Table 1. Distributions of socio-demographic characteristics of athletes.

Variable	Frequency	Percentage
Level of Competition		
Recreational	2	1.7
College/University	24	20.0
County/Regional	5	4.2
National	53	44.2
International	14	11.7
Professional	22	18.3
Total	120	100
Sports Participation		
Athletics	23	19.2
Hockey	33	27.5
Basketball	14	11.7
Boxing	10	8.3
Soccer	40	33.3
Total	120	100
Years of Sports		
1–3	13	10.8
4–6	39	32.5
7–9	28	23.3
10–12	29	24.2
>12	11	9.2
Total	120	100
Hours of Training		
1–3	17	14.2
4–6	22	18.3
7–9	20	16.7
10–12	6	5.0
13–15	29	24.2
>15	26	21.7
Total	120	100

Table 2 shows the mean and SD values of the factors of athletes' expectations. The most

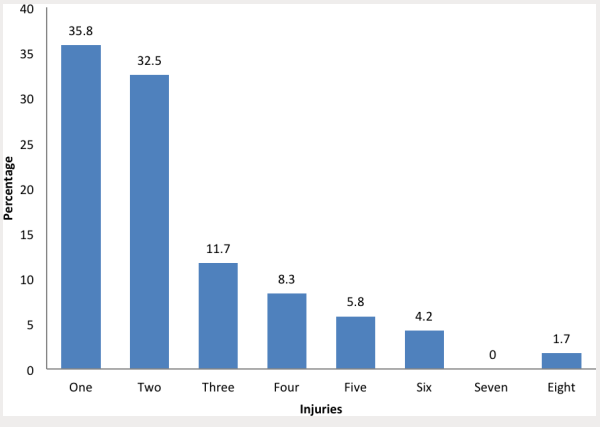

Fig. 1. Percentage distribution of sports-related injury frequencies.

Table 2. The mean and SD scores of the factors of athletes' expectations.

Factor	Mean	SD
Acceptance	5.92	0.76
Motivation	5.44	0.08
Attractiveness	5.63	0.89
Responsibility	6.23	1.43
Directiveness	6.11	0.77
Empathy	5.65	0.63
Confrontation	5.79	0.80
Nurturance	6.02	0.72
Genuineness	6.14	0.73
Openness	5.79	0.91
Outcome	6.13	0.77

influencing factors that affect athletes' expectations were directiveness (mean = 6.11, SD = 0.77), nurturance (mean = 6.02, SD = 0.72) and genuineness (mean = 6.02, SD = 0.72).

The results revealed no significant difference in the mean scores of the various factors between males and females except confrontation ($p = 0.032$), which was statistically significant. Table 3 shows the comparison of mean scores of the various factors among gender, previous physiotherapy experience and use of mental skills.

The study revealed that the differences in the types of injuries caused no significant difference in the mean scores of the various factors ($p > 0.05$). Table 4 shows the comparison of mean scores of the various factors among injury types.

Table 5 showed that there was no significant difference in the mean scores of the various factors between athletes who had previously experienced physiotherapy and those who had not ($p > 0.05$). Table 6 showed that the study did not reveal any significant difference in the mean scores of the various factors between athletes who had experienced mental skills training and those who had not ($p > 0.05$).

Discussion

The study shows that majority of athletes who took part in this study from Greater Accra Region are males. This observation could be due to the impression that sports require vigorous activities that are best suited for males. The average age of 22.5 ± 3.6 years shows youthful involvement in sports, which is a good prospect for the nation and personal development. The study revealed that most of the athletes had been involved in their

Table 3. Comparison of mean scores of the various factors among gender, previous physiotherapy experience and use of mental skills.

Factor	Gender	Mean	*p*-Value	Physio experience	Mean	*p*-Value	Mental skills usage	Mean	*p*-Value
Acceptance	Male	5.89	0.653	Yes	5.89	0.437	Yes	5.87	0.835
	Female	5.95		No	5.95		No	5.94	
Motivation	Male	5.31	0.707	Yes	5.31	0.639	Yes	5.13	0.052
	Female	5.54		No	5.54		No	5.57	
Attractiveness	Male	5.56	0.195	Yes	5.56	0.877	Yes	5.54	0.717
	Female	5.69		No	5.69		No	5.67	
Responsibility	Male	6.69	0.815	Yes	6.69	0.396	Yes	6.80	0.302
	Female	5.88		No	5.88		No	5.98	
Directiveness	Male	6.06	0.748	Yes	6.06	0.682	Yes	6.04	0.707
	Female	6.13		No	6.13		No	6.13	
Empathy	Male	5.53	0.925	Yes	5.53	0.738	Yes	5.51	0.154
	Female	5.72		No	5.72		No	5.70	
Confrontation	Male	5.64	0.032*	Yes	5.64	0.883	Yes	5.59	0.069
	Female	5.89		No	5.89		No	5.87	
Nurturance	Male	5.99	0.337	Yes	5.99	0.752	Yes	5.84	0.103
	Female	6.04		No	6.04		No	6.09	
Genuineness	Male	6.10	0.770	Yes	6.10	0.066	Yes	6.01	0.234
	Female	6.16		No	6.16		No	6.19	
Openness	Male	5.46	0.442	Yes	5.46	0.333	Yes	5.76	0.468
	Female	6.02		No	6.02		No	5.79	
Outcome	Male	6.10	0.270	Yes	6.10	0.486	Yes	6.02	0.113
	Female	6.15		No	6.15		No	6.17	

Table 4. Comparison of mean scores of the various factors among injury types.

Factor	Injury type	Mean	*p*-Value
Acceptance	Acute	5.93	
	Chronic	5.96	0.649
	Both	5.82	
Motivation	Acute	5.52	
	Chronic	5.21	0.188
	Both	5.19	
Attractiveness	Acute	5.68	
	Chronic	5.57	0.505
	Both	5.42	
Responsibility	Acute	6.30	
	Chronic	6.13	0.538
	Both	5.92	
Directiveness	Acute	6.12	
	Chronic	6.25	0.681
	Both	5.92	
Empathy	Acute	5.61	
	Chronic	5.95	0.510
	Both	5.60	
Confrontation	Acute	5.76	
	Chronic	5.66	0.275
	Both	6.00	
Nurturance	Acute	6.02	
	Chronic	5.87	0.810
	Both	6.07	
Genuineness	Acute	6.15	
	Chronic	5.95	0.422
	Both	6.21	
Openness	Acute	5.83	
	Chronic	5.77	0.326
	Both	5.55	
Outcome	Acute	6.18	
	Chronic	5.95	0.322
	Both	5.97	

choice of sport for over 4–6 years. This might be due to their intense interest in sports during their teens, considering the average age of the athletes. A great number of athletes train for over 13–15 h per week, which could be as a result of their trainers/coaches scheduling the training times to meet competition demands.

Athletes in the Greater Accra Region had high expectations for all the 11 factors. This shows that the athletes had high expectations of the outcome of physiotherapy sessions and the physiotherapists treating them while the athletes themselves needed to be committed to their rehabilitation.

The athletes reported highest expectations for responsibility, directiveness, genuineness and

Table 5. Comparison of mean scores of the various factors among competition levels.

Factor	Competition level	Mean	*p*-Value
Acceptance	Recreational	6.33	
	College/University	5.83	
	County/Regional/State	5.60	0.435
	National	5.83	
	International	6.23	
	Professional	6.09	
Motivation	Recreational	6.16	
	College/University	5.36	
	County/Regional/State	5.20	0.290
	National	5.25	
	International	5.78	
	Professional	5.75	
Attractiveness	Recreational	5.16	
	College/University	5.61	
	County/Regional/State	5.06	
	National	5.52	0.121
	International	5.69	
	Professional	6.04	
Responsibility	Recreational	6.25	
	College/University	6.14	
	County/Regional/State	6.50	0.024*
	National	6.37	
	International	5.92	
	Professional	6.09	
Directiveness	Recreational	5.75	
	College/University	6.20	
	County/Regional/State	6.30	0.324
	National	5.86	
	International	6.61	
	Professional	6.25	
Empathy	Recreational	5.25	
	College/University	5.41	
	County/Regional/State	5.90	0.140
	National	5.50	
	International	6.07	
	Professional	5.93	
Confrontation	Recreational	5.66	
	College/University	5.34	
	County/Regional/State	5.73	
	National	5.85	0.241
	International	6.04	
	Professional	5.98	
Nurturance	Recreational	6.66	
	College/University	5.90	
	County/Regional/State	5.86	
	National	5.89	0.076
	International	6.11	
	Professional	6.36	
Genuineness	Recreational	7.00	
	College/University	6.22	
	County/Regional/State	6.20	0.076
	National	5.99	
	International	6.28	

Table 5. (*Continued*)

Factor	Competition level	Mean	*p*-Value
	Professional	6.22	
Openness	Recreational	5.50	
	College/University	5.60	
	County/Regional/State	4.80	0.073
	National	5.81	
	International	5.82	
	Professional	6.15	
Outcome	Recreational	6.25	
	College/University	5.89	
	County/Regional/State	6.20	0.576
	National	6.15	
	International	6.35	
	Professional	6.18	

Note: * = Significant.

outcome. This indicates that athletes expect a high level of professionalism from the physiotherapist as well as maturity from themselves in terms of decision-making. These findings are similar to the ones reported by Lee.[10] The athletes also expect the physiotherapists to explain the causes of their injuries and outcomes of the rehabilitation to them. This would give the athlete a fair idea of how the treatment will go and its benefits. This could make the athlete feel involved and be a part of the rehabilitation.

Table 6. Comparison of athletes' expectations among selected demographic characteristics.

		p-Value
	Gender	
Total Expectation	Male	
	Female	0.637
	Total	
	Physiotherapy Experience	
Total Expectation	Yes	0.942
	No	
	Total	
	Mental Skills Usage	
Total Expectation	Yes	0.2
	No	
	Total	
	Competition Level	
Total Expectation	Recreational	
	College/University	
	County/Regional/State	0.0290*
	National	
	International	
	Professional	
	Total	
	Injury Type	
Total Expectation	Acute	
	Chronic	0.910
	Both	

Note: * = Significant.

The athletes had moderate expectations for motivation. This could be due to the fact that athletes know the importance of rehabilitation and the consequences of late recovery. They expect some kind of motivation from the physiotherapists to attend the rehabilitation sessions whether painful or not. The findings are contrary to the ones reported by Washington-Lofgren *et al.*[11] This asserts the fact that educating the athlete regarding what is expected in addition to the injury may in itself reduce the athlete's anxiety by eliminating the fear of the unknown.

The study showed differences in athletes' expectations for confrontation. Females had higher expectations for confrontations and openness than males. This could be due to the fact that females are more particular about the things they do and their consequences. This however contributes to their high scores as compared to males. Clement and Shannon[5] reported contrary results, thus the results from this study could be due to the effort and dedication the athletes give to their sports and the implications injuries have on their career.

There were no significant differences between athletes' expectations about physiotherapy and the type of injury they had during rehabilitation. The study revealed that chronically injured athletes had high expectations of the physiotherapist to be genuine and to be able to motivate. This is in congruence with the findings of Roh and Perna.[15] Chronically injured athletes had the highest expectations for empathy and athletes with both injury types also recorded the highest expectations for confrontation. This could be due to the severity of the injuries they sustained and its possible impact on their career.

This study revealed no significant difference between athletes' expectations of physiotherapy and their previous experience with physiotherapy. Majority of the participants had had no physiotherapy as part of their previous injury rehabilitation. This could be due to the moderate awareness and underutilization of physiotherapy services by sports teams in Ghana. Most of the teams employ the services of masseurs who are professionally trained to massage. Majority of the participants in this study reported never using mental skills, for

goal setting, relaxation and mental imagery, as part of the injury rehabilitation. Athletes with previous use of mental skills had moderate expectations for motivation, empathy, confrontation, nurturance and outcome. Though they appreciated their usage, they were somewhat worried about the absence of these skills during their training sessions and that contributed to their moderate expectations. This corroborates with the findings of Ludewig[8] that athletic trainers perceived physiotherapists to be more important for their role as motivating athletes during injury rehabilitation than perceived by the athletes.

The findings of the study showed no significant difference in the various athletes' competition levels except responsibility. Athletes who played at the national level had moderate expectations for all the factors except openness and outcome for which they had high expectations. This could be attributed to the fact that national teams usually have physiotherapists in their medical teams. The athletes get access to these services and this contributed to their moderate–high expectations as compared to athletes competing at other levels. These findings were however contrary to those of Lee[10] that professional athletes have higher expectations for nurturance than recreational or national-level athletes.

Conclusion

The findings of this study indicate that athletes in Greater Accra Region have high expectations of physiotherapy for sport injury rehabilitation. Competition level had a significant association with athletes' expectations about physiotherapy in sport injury rehabilitation. There was also underutilization of physiotherapy services among the sports teams.

Based on the findings of this study, it is recommended that sports physiotherapists in Accra involve their injured athletes in the rehabilitation programs by giving them all the information about their injuries and how the rehabilitation will help.

Acknowledgments

We would like to acknowledge all athletes who took time off their busy schedules to participate in this study.

Ethics

Ethics approval was sought from the Ethics and Protocol Review Committee of the School of Biomedical and Allied Health Sciences, College of Health Sciences, University of Ghana.

Conflict of Interest

There were no competing interests from all authors in this study.

Funding/Support

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Author Contributions

Selorm Afidemenyo and Jonathan Quartey contributed to the study design and collected data. Jonathan Quartey, Selorm Afidemenyo and Samuel Koranteng Kwakye analyzed the data obtained. Jonathan Quartey and Samuel Koranteng Kwakye sourced and reviewed relevant literature. Jonathan Quartey, Selorm Afidemenyo and Samuel Koranteng Kwakye wrote and also reviewed the manuscript for the important intellectual content. Jonathan Quartey, Selorm Afidemenyo and Samuel Koranteng Kwakye revised the final draft and approved the final version of the manuscript for submission.

Appendix A. Ethics Approval

SCHOOL OF ALLIED HEALTH SCIENCES
COLLEGE OF HEALTH SCIENCES
UNIVERSITY OF GHANA
ACADEMIC AFFAIRS

Phone: +233-0302-687974/5
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My Ref. No. SAHS/10273367
Your Ref. No.

P. O .Box KB 143
Korle Bu
Accra
Ghana

10th July, 2012

Ms Selorm Afidemenyo,
Dept. of Physiotherapy,
SAHS.
Korle Bu.

Dear Ms Afidemenyo,

ETHICS CLEARANCE

Ethics Identification Number: SAHS – ET./10273367/AA/26A/2012-2013.

Following a meeting of the Ethics and Protocol Review Committee of the School of Allied Health Sciences held on Friday 6th July, 2012, I write on behalf of the Committee to approve your research proposal as follows:

TITLE OF RESEARCH PROPOSAL: **"Athletes expectation about physiotherapy in sports injury rehabilitation in Greater Accra Region".**

This approval requires that you submit six-monthly review reports of the protocol to the Committee and a final full review to the Committee on completion of the research. The Committee may observe the procedures and records of the research during and after implementation.

Please note that any significant modification of the research must be submitted to the Committee for review and approval before its implementation.

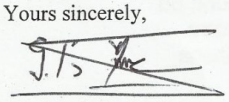
You are required to report all serious adverse events related to this research to the Committee within seven (7) days verbally and fourteen (14) days in writing.

As part of the review process, it is the Committee's duty to review the ethical aspects of any manuscript that may be produced from this research. You will therefore, be required to furnish the Committee with any manuscript for publication.

Please always quote the ethical identification number in all future correspondence in relation to this protocol.

Thank you.

Yours sincerely,



Dr. (Maj. Rtd.) George Asare
(Chairman, Ethics and Protocol Review Committee)

cc Ag. Dean
Co-ordinator, Dept. of Physiotherapy
Senior Assistant Registrar

Appendix B. Data Capturing Form

DEMOGRAPHIC INFORMATION SHEET

Please answer the following questions about yourself and your involvement in sport.

(1) What is your gender?
   (a) Male
   (b) Female

(2) How old are you?.....

(3) Are you in school? YES/NO
   (a) If yes, what year are you in school? .....
   (b) If no, what is your highest qualification? .....

(4) What is your level of competition?
   (a) Recreational
   (b) College/University
   (c) County/Regional/State
   (d) National
   (e) International
   (f) Professional

(5) What sport(s) are you currently involved in?.....

(6) How many years have you been involved in your sport?.....

(7) Typically how many hours do you train/week?.....

(8) How many sport-related injuries have you had?.....

(9) What type of injuries have you had?
   (a) Acute (happened suddenly during sport)
   (b) Chronic (have occurred over time, e.g., overuse injuries)
   (c) Both

(10) How would you classify the severity of MOST of your injuries?
   (a) Minor injury (prevents participation in practice/competition for up to 8 days)
      (i) How many?.....
   (b) Moderate injury (prevents participation in practice/competition for 8–21 days)
      (i) How many?.....
   (c) Severe injury (prevents participation in practice/competition for more than 21 days)
      (i) How many?.....
   (d) Catastrophic injury (e.g., career ending, permanent physical disability)
      (i) How many?.....

(11) Do you have any past experiences with physiotherapy? YES/NO
   (a) If yes, how many of your past injuries have required physiotherapy treatment? .....

(12) Have you ever used mental skills (self-talk, mental imagery, goal setting, relaxation, etc.) as part of your sport-injury rehabilitation? YES/NO
   (a) If yes, what did you use?.....
   (b) And did the physiotherapists teach you how to use the skills? YES/NO

(13) If yes to (12), do you believe that the use of mental skills helped you rehabilitate faster or more completely from sport injury? YES/NO

Appendix C. EAAT Questionnaire

Indicate your level of agreement with each of the statements by ticking the number that corresponds to your feelings toward each statement. Answer the following questions using the scale below:

1 = Strongly Disagree; 2 = Disagree; 3 = Moderately Disagree; 4 = Neutral; 5 = Moderately Agree; 6 = Agree; 7 = Strongly Agree.

I EXPECT TO...

(1) Take psychological tests.	[1] [2] [3] [4] [5] [6] [7]
(2) Like the physiotherapist.	[1] [2] [3] [4] [5] [6] [7]
(3) Gain some information about how to solve problems.	[1] [2] [3] [4] [5] [6] [7]
(4) Openly express my emotions regarding my problems and myself.	[1] [2] [3] [4] [5] [6] [7]
(5) Take responsibility for making my own decisions.	[1] [2] [3] [4] [5] [6] [7]
(6) Talk about my present concerns.	[1] [2] [3] [4] [5] [6] [7]

I EXPECT TO...

(7) Get practice in relating openly and honestly to another person within the physiotherapist–athlete relationship.	[1] [2] [3] [4] [5] [6] [7]

(8) Enjoy my visit with the physiotherapist. [1] [2] [3] [4] [5] [6] [7]
(9) Practice some things I need to learn. [1] [2] [3] [4] [5] [6] [7]
(10) Get a better understanding of the injury and myself. [1] [2] [3] [4] [5] [6] [7]
(11) Complete physiological assessments. [1] [2] [3] [4] [5] [6] [7]
(12) Continue the physiotherapy visits for at least a few weeks, even if at first I am not sure it will help. [1] [2] [3] [4] [5] [6] [7]

I EXPECT TO...

(13) See the physiotherapist for more than three visits. [1] [2] [3] [4] [5] [6] [7]
(14) Never need to visit the physiotherapist again. [1] [2] [3] [4] [5] [6] [7]
(15) Enjoy being with the physiotherapist. [1] [2] [3] [4] [5] [6] [7]

[1 = Strongly Disagree; 2 = Disagree; 3 = Moderately Disagree; 4 = Neutral; 5 = Moderately Agree; 6 = Agree; 7 = Strongly Agree.]

(16) Continue to visit the physiotherapist even though it may be painful or unpleasant at times. [1] [2] [3] [4] [5] [6] [7]
(17) Contribute as much as I can in terms of expressing my feelings and discussing them. [1] [2] [3] [4] [5] [6] [7]
(18) Work with the physiotherapist in setting my rehabilitation goals. [1] [2] [3] [4] [5] [6] [7]

I EXPECT TO...

(19) Find that the rehabilitation relationship will help the physiotherapist and me in identifying problems on which I need to work. [1] [2] [3] [4] [5] [6] [7]
(20) Become better able to help myself in the future. [1] [2] [3] [4] [5] [6] [7]
(21) Feel safe enough with the physiotherapist to really say how I feel. [1] [2] [3] [4] [5] [6] [7]
(22) Improve my relationships with others. [1] [2] [3] [4] [5] [6] [7]
(23) Ask the physiotherapist to explain what he or she means whenever I do not understand something that is said. [1] [2] [3] [4] [5] [6] [7]
(24) Work on my concerns outside the physiotherapist visit. [1] [2] [3] [4] [5] [6] [7]

I EXPECT THE SPORT INJURY REHABILITATION PHYSIOTHERAPIST TO...

(25) Explain what is wrong. [1] [2] [3] [4] [5] [6] [7]
(26) Help me identify and label my feelings so I can better them. [1] [2] [3] [4] [5] [6] [7]
(27) Tell me what to do. [1] [2] [3] [4] [5] [6] [7]
(28) Know how I feel even when I cannot say quite what I mean. [1] [2] [3] [4] [5] [6] [7]
(29) Know how to help me. [1] [2] [3] [4] [5] [6] [7]

I EXPECT THE SPORT INJURY REHABILITATION PHYSIOTHERAPIST TO...

(30) Help me identify particular situations where I have problems. [1] [2] [3] [4] [5] [6] [7]
(31) Give encouragement and reassurance. [1] [2] [3] [4] [5] [6] [7]

[1 = Strongly Disagree; 2 = Disagree; 3 = Moderately Disagree; 4 = Neutral; 5 = Moderately Agree; 6 = Agree; 7 = Strongly Agree.]

(32) Help me to know how I am feeling by putting my feelings into words for me. [1] [2] [3] [4] [5] [6] [7]
(33) Be a "real" person and not just a person doing a job. [1] [2] [3] [4] [5] [6] [7]
(34) Help me discover what particular aspects of my behavior are relevant to my problems. [1] [2] [3] [4] [5] [6] [7]

I EXPECT THE SPORT INJURY REHABILITATION PHYSIOTHERAPIST TO...

(35) Inspire confidence and trust. [1] [2] [3] [4] [5] [6] [7]
(36) Frequently offer me advice. [1] [2] [3] [4] [5] [6] [7]
(37) Be honest with me. [1] [2] [3] [4] [5] [6] [7]
(38) Be someone who can be counted on. [1] [2] [3] [4] [5] [6] [7]
(39) Be friendly and warm towards me. [1] [2] [3] [4] [5] [6] [7]

I EXPECT THE SPORT INJURY REHABILITATION PHYSIOTHERAPIST TO...

(40) Help me solve my problems. [1] [2] [3] [4] [5] [6] [7]
(41) Discuss his or her attitudes and relate them to my problem. [1] [2] [3] [4] [5] [6] [7]
(42) Give me support. [1] [2] [3] [4] [5] [6] [7]
(43) Help me decide what mental plan is best. [1] [2] [3] [4] [5] [6] [7]
(44) Fix my problem(s). [1] [2] [3] [4] [5] [6] [7]

I EXPECT THE SPORT INJURY REHABILITATION PHYSIOTHERAPIST TO...

(45) Know how I feel at times, without my having to speak. [1] [2] [3] [4] [5] [6] [7]
(46) Do most of the talking. [1] [2] [3] [4] [5] [6] [7]
(47) Respect me as a person. [1] [2] [3] [4] [5] [6] [7]
(48) Help me to regain my pre-injury level of fitness. [1] [2] [3] [4] [5] [6] [7]
(49) Discuss his or her experiences and relates them to my problems. [1] [2] [3] [4] [5] [6] [7]

[1 = Strongly Disagree; 2 = Disagree; 3 = Moderately Disagree; 4 = Neutral; 5 = Moderately Agree; 6 = Agree; 7 = Strongly Agree.]

I EXPECT THE SPORT INJURY REHABILITATION PHYSIOTHERAPIST TO...

(50) Praise me when I show improvement. [1] [2] [3] [4] [5] [6] [7]
(51) Make me face up to the differences between what I say and how I behave. [1] [2] [3] [4] [5] [6] [7]
(52) Set clear, specific and measurable goals for rehabilitation. [1] [2] [3] [4] [5] [6] [7]
(53) Talk freely about himself or herself. [1] [2] [3] [4] [5] [6] [7]
(54) Have no trouble getting along with people. [1] [2] [3] [4] [5] [6] [7]

I EXPECT THE SPORT INJURY REHABILITATION PHYSIOTHERAPIST TO...

(55) To use psychological interventions (e.g., imagery, relaxation) during physiotherapy treatment. [1] [2] [3] [4] [5] [6] [7]
(56) Like me. [1] [2] [3] [4] [5] [6] [7]
(57) Be someone I can really trust. [1] [2] [3] [4] [5] [6] [7]
(58) Like me in spite of my weaknesses or strengths that he or she discovers about me. [1] [2] [3] [4] [5] [6] [7]
(59) Make me face up to the differences between how I see myself and how I am seen by others. [1] [2] [3] [4] [5] [6] [7]
(60) Be someone who is calm and easygoing. [1] [2] [3] [4] [5] [6] [7]

I EXPECT THE SPORT INJURY REHABILITATION PHYSIOTHERAPIST TO...

(61) Assist me on how to use positive self-talk. [1] [2] [3] [4] [5] [6] [7]
(62) Point out to me the differences between what I am and what I want to be. [1] [2] [3] [4] [5] [6] [7]
(63) Just give me information. [1] [2] [3] [4] [5] [6] [7]
(64) Get along well in the world. [1] [2] [3] [4] [5] [6] [7]

[1 = Strongly Disagree; 2 = Disagree; 3 = Moderately Disagree; 4 = Neutral; 5 = Moderately Agree; 6 = Agree; 7 =Strongly.]

(65) Be able to introduce me to other athletes who have had and are now healed from a similar injury. [1] [2] [3] [4] [5] [6] [7]
(66) Motivate me to attend physiotherapy sessions. [1] [2] [3] [4] [5] [6] [7]

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Research Paper

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Immediate effects of a novel walking assist device with auxiliary illuminator on patients after acute strokes

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Background: Many patients after acute stage of stroke are present with abnormal gait pattern due to weakness or hypertonicity of the affected limbs. Facilitation of normal gait is a primary goal of rehabilitation on these patients.
Objective: We aimed to investigate whether walking assist device with auxiliary illuminator (quad-cane with laser) providing visual feedback during ambulation could improve parameters of gait cycle immediately among patients with subacute and chronic stroke.
Methods: This was a cross-sectional study and 30 participants (male 23, female 7, group 1) with mean age 60.20 ± 11.12 years were recruited. Among them, 22 used ankle-foot orthosis [(AFO), group 2] and 8 did not use AFO (group 3) at usual walking. All the participants walked along a strait corridor with even surface for

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20 m without and with using a quad-cane with laser, respectively. A gait analyzer (Reha-Watch1 system) was used to measure the changes of the parameters of gait cycle, including stride length, cadence, gait speed, stance phase, swing phase, duration of single support and double support, the angle between toes and the ground at the time of toe-off (the toe-off angle) and the angle between calcaneus and the ground at the time of heel-strike (the heel-strike angle), before and with the use of a quad-cane with laser.
Results: The increase in the heel-strike angle reached a significant difference in groups 1 2, and 3 ($p = 0.02, < 0.01,$ and $= 0.05,$ respectively). However, the stride length, the gait speed, the cadence, percentage of the stance phase, swing phase, single-support phase, and double-support phase in a gait cycle, and the toe-off angle showed no significant change with the use of quad-cane with laser.
Conclusion: Patients after acute stroke had an immediate and significant increase in the heel-stroke angle by using a quad-cane with laser during ambulation, which might help the patients to reduce knee hyperextension moment and lessen the pressure of heel at loading phase.

Keywords: Gait; stroke; walking assist device; auxiliary illuminator.

Introduction

Stroke can result in brain damage, loss of functional activity, even disability or handicap among patients.[1] About 75% of patients with stroke suffer from walking disability that may lead to a high risk of falling and inability to be independent in daily life.[2,3] It is very important for stroke survivors to receive intensive rehabilitation programs to recover their walking ability after acute stage of stroke.[4] In order to improve dynamic balance during walking on uneven surface and the ability to adapt and overcome the barrier in different environments, repeated training and massed practice of gait during rehabilitation is crucial.[5] The different assistive devices and the strategies of motor relearning used in gait training both affect the duration and clinical effect of the training.

Since walking consists of a number of consecutive gait cycles that must be coordinated by multiple systems of the body finely, aging and diseases both can cause impairment in walking.[6] Patients with stroke are often present with abnormal gait pattern during walking due to hemiplegic extremities.[7] It is estimated that 48% to 82% and 44% to 62% of the patients following stroke occur temporal and spatial inter-limb asymmetries, respectively.[8,9] Compared with normal adults, abnormal gait patterns of patient with stroke include slower gait speed, shorter stride length, longer phase of double support, shorter phase of single leg swing, lesser cadence, and narrower stride width resulting from hypertonicity of hip adductors; meanwhile, due to the weakness of hip internal rotators, knee flexors and extensors, compensatory circumduction gait is common as well.[10,11] The abnormal gait patterns mentioned above might affect walking function, which leads to increased likelihood of falls, limitation in activities of daily living (ADL), and diminished quality of life.[12]

Integration of several human systems, such as musculoskeletal system, nervous system, visual system, and cognitive system, are necessary for the motor recovery in adult patients following stroke.[13] Previous studies had proved that patients with stroke will achieve statistically significant improvement in balance, functional independence and gait control after receiving intensive rehabilitation program (60 min per time, once per week for three consecutive weeks) focusing on gait training.[14,15] In order to achieve independence of ADLs in patients with stroke, locomotion and ambulation trainings are the most common and important programs in rehabilitation of stroke during subacute and chronic stages. The initial use of walking aids has been suggested to improve the quality, stability, and also prevent falls in stroke patients in the rehabilitation.[16,17] Quad-canes are one of the most common walking aids in gait training among patients after stroke since most of them presented with hemiplegic pattern. It had been proved that quad-canes could improve symmetry[18] and help to achieve normal muscle activation patterns[19] in patients with subacute stroke who have asymmetric gait. Interactive therapy with visual feedback appears to be an important option to engage patients' participation and could be a useful approach to stroke rehabilitation.[20,21] To the best of our knowledge, no available study evaluated the clinical effectiveness in the use of quad-cane with auxiliary illuminator (quad-cane with laser) as

visual feedback system among adult stroke patients in subacute and chronic stage. We aimed to provide visual feedback to the stroke patients by using a quad-cane with laser to explore the immediate effects on the parameters of gait cycle.

Methods

Ethics

This study was approved by the Institutional Review Board of Kaohsiung Veterans General Hospital (Number: VGHKS17-CT8-11). It was also conducted at Kaohsiung Veterans General Hospital from December 2017 to May 2018. All patients provided the informed consent after explanation by the study members and before the rehabilitation programs.

Participants

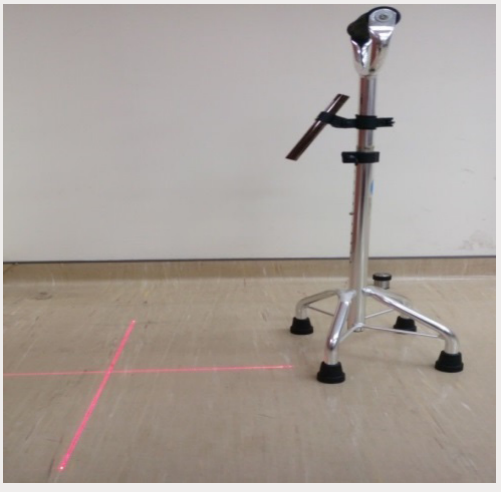
This was a cross-sectional study. We recruited patients with subacute and chronic stroke who received rehabilitation treatment from the outpatient clinic of the rehabilitation department of one medical center of southern Taiwan. The inclusion criteria were the following: Stroke patients (1) after the acute stage with stable vital signs, (2) with hemiplegic gait, (3) with sufficient cognition that could follow the instructions and procedure, (4) walk independently for a distance of more than 20 m with or without the use of a walking aid. Stroke patients with other neurological diseases like Parkinsonism, myopathy, multiple sclerosis, and spinal cord injury that might interfere with walking ability were excluded.

To determine the sample size, the G*Power software (version 3.1.9.2 for Windows) was used. The alpha level and the power were set as 0.05 and 0.8. The effect size was set at high effect (0.8) and the minimal estimated sample size was 15 subjects.

Outcome measured

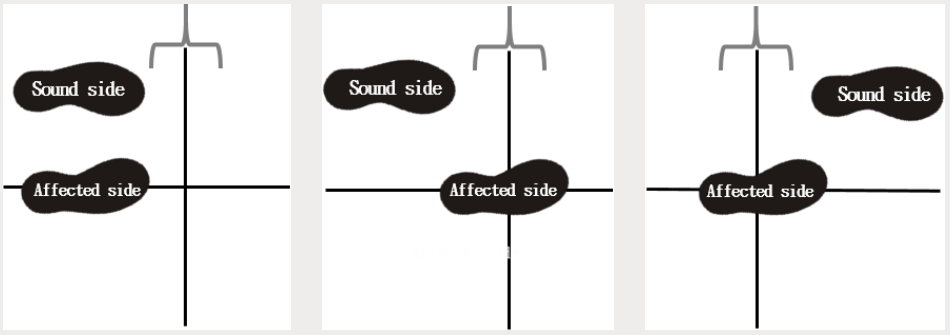
Participants were asked to walk on 30-m long and 4-m wide corridor with even surface for 20 m with regular quad-cane (without auxiliary illuminator) at their usual walking speed first. After a 10-min break, participants were asked to walk again under the condition as the same as the previous one except that they used a walking assist device with auxiliary illuminator during walking once. The quad-cane with laser was consisted of a quad-cane and a laser pointer (which was placed on the shaft of the quad-cane with two laser beams vertical to each other, Fig. 1).

Participants were requested to walk by the three-point gait with the walking assist device on the sound site and the sound lower extremity parallel to one laser beam first. Then, participants moved their hemiplegic lower extremity to the cross made by the two laser beams by the illuminator with the mid-foot right over the crossing point. Last, participants were asked to move their sound lower extremity over the other laser beam and make the heel of the sound site forward the toes of the hemiplegic side (Fig. 2). The laser beam can be adjusted to individual's step length. The length of each patient would be set as big as his/her foot print approximately. The whole study procedure was well explained and under the supervision of a well-trained therapist (Xin-yu Liu). Parameters of gait cycle, including stride length, cadence, gait speed, duration of stance phase, duration of swing phase, duration of single support and double support during the gait cycle, angle between the foot and the ground at the time of heel strike in sagittal plane during a gait cycle (heel-strike angle), and angle between toes and the ground at the time of toe off in the sagittal plane during a gait cycle (toe-off angle) were measured by a gait analyzer (RehaWatch®; HASOMED GmbH, Magdeburg, Germany) in each walking.



Notes: The device was consisted of a quad-cane and a laser pointer. The laser pointer was placed on the shaft of the quad-cane with two laser beams vertical to each other which made a cross and provided with visual feedback.

Fig. 1. Walking assist device with auxiliary illuminator.



(a) (b) (c)

Fig. 2. Sequence of gait with the use of walking assistive device with auxiliary illuminator (affected side is the right): (a) Participants were requested to walk by the three-point gait with the walking assist device on the sound site and the sound lower extremity parallel to one laser beam first. (b) Then, participants moved their hemiplegic lower extremity to the cross made by the two laser beams by the illuminator with the mid-foot right over the crossing point. (c) Last, participants were asked to move their sound lower extremity over the other laser beam and make the heel of the sound site forward the toes of the hemiplegic side.

RehaWatch® is an inertial sensor-based gait analysis system with measurement sensors attached to the lateral ankle using a special device (Fig. 3). Each sensor contains three accelerometers and three gyroscopes measuring foot motion in six degrees of freedom. The measurement range of the accelerometers is ±5 g and gyroscopes ±600°/s. The sampling rate is 512 Hz. Gait measurements are performed in offline mode. The primary gait event is heel-strike and all other gait events are identified relative to heel-strike. Spatiotemporal gait parameters and gait phases are calculated automatically.[22] It has high reliability. Lots of studies have been published and proved the reliability by using RehaWatch® in health adults and populations with different diseases.[23] The angle of

(a) (b)

Notes: Reha-Watch® is an inertial sensor-based gait analysis system with measurement sensors attached to the lateral ankle. (a) shows the placement of the system on the affected foot without AFO use and (b) shows the placement of the system on the affected foot with anterior-leaf AFO use.

Fig. 3. The RehaWatch® system with the sensors on the lateral side of the shoes.

the ankle more than 0° means the direction of dorsiflexion and less than zero means the direction of plantar flexion.

Statistical analysis

SPSS for Windows version 19.0 (Released 2010, Armonk, NY: IBM Corp) was used for all analyses. Continuous data were expressed as mean ± standard deviation and categorical variables were presented as absolute numbers or percentages. Normality and homoscedasticity were checked prior to each analysis. The chi-square test was used to test for differences in the distribution between categorized variables. The independent *t*-test was used for normally distributed variables, whereas the Mann–Whitney U test was used for non-normally distributed variables for comparison of parameters of gait cycle between the first and the second walkings. *P*-value ≤ 0.05 was considered statistically significant.

Results

Thirty participants met the study criteria and no one dropped out. The recruited participant consisted of 23 males and 7 females with an average age of 60.20 ± 11.12 years. Among them, 20 patients had right hemiplegic extremities and 10 had left hemiplegia/hemiparesis. In terms of stroke types, 15 were hemorrhagic strokes and 15 were ischemic stroke. Subgroup analysis was done between participants walked with ($n = 22$) or without ($n = 8$) the support of ankle-foot orthosis (AFO). The AFOs used by the participants were all anterior-leaf design, which could provide partial mobility of the ankle joint and retain the ankle joint strategy. The basic characteristics of the two subgroups showed no significant difference in the statistical analysis. Descriptive characteristics of the participants are presented in Table 1.

Table 2 provides the immediate effects on parameters of gait cycle with the use of a quad-cane

Table 1. Descriptive characteristics of the stroke patients with subgroup (patients with or without use of AFO) analysis.

	Total patients ($n = 30$)	Patients used AFO ($n = 22$)	Patients did not use AFO ($n = 8$)	*P*-value[a]
Height (cm)	166.37 ± 8.41	166.00 ± 9.06	168.13 ± 7.59	0.56
Weight (kg)	66.27 ± 10.82	65.27 ± 10.63	69.00 ± 11.59	0.41
Stroke duration (months)	33.83 ± 29.41	32.14 ± 30.12	38.58 ± 28.58	0.69
Age (years)	60.20 ± 11.12	60.14 ± 11.91	61.75 ± 8.48	0.73
Gender (Male/Female)	(23/7)	(16/6)	(7/1)	0.64
Stroke side (right/left)	(20/10)	(14/8)	(6/2)	0.68
Stroke type	(15/15)	(13/9)	(2/6)	0.22

Notes: [a]The chi-square test and independent *t*-test were used to test for differences in the distribution between categorized variables and continuous variables between stroke patients who walked with AFO or not.

Table 2. Immediate effects of gait cycles in patients with stroke before and after using the walking assist device with auxiliary illuminator ($n = 30$).

	Not using illuminator (95% C.I.)	Using illuminator (95% C.I.)	*P*-value
Stride length (m)	0.93 ± 0.59 (0.74–1.08)	0.92 ± 0.53 (0.79–1.16)	0.91
Gait speed (m/s)	0.66 ± 0.87 (0.40–0.91)	0.57 ± 0.68 (0.39–0.89)	0.66
Cadence (step/min)	39.76 ± 15.89 (33.12–45.75)	36.33 ± 12.95 (31.98–40.09)	0.36
Stance phase (%)	76.86 ± 9.95 (72.92–80.72)	76.00 ± 12.77 (71.67–79.88)	0.76
Affected swing phase (%)	23.15 ± 9.95 (19.28–27.09)	24.05 ± 12.77 (20.13–28.33)	0.76
Affected single-support phase (%)	15.77 ± 7.31 (13.71–20.33)	14.71 ± 5.62 (12.84–17.73)	0.53
Double-support phase (%)	17.91 ± 11.48 (14.48–21.62)	18.95 ± 10.78 (15.53–22.71)	0.72
Heel-strike angle (degree)	0.34 ± 5.76 (−2.68–3.11)	4.00 ± 6.01 (1.11–6.75)	0.02*
Toe-off angle (degree)	−11.23 ± 12.98 (−18.73–−7.97)	−11.26 ± 11.31 (−17.85–−7.84)	0.99

Notes: *$p < 0.05$.
95% C.I.: 95% confidence interval; heel-strike angle: angle between calcaneus and the ground at the time of heel strike during a gait cycle; toe-off angle: angle between toes and the ground at the time of toe-off during a gait cycle.

Table 3. Immediate effects of gait cycles in patients with chronic stroke who use AFOs and those who do not use AFOs after using the walking assist device with auxiliary illuminator.

	Used AFOs ($n = 22$)			Did not use AFOs ($n = 8$)		
	No Illuminator (95% C.I.)	Illuminator use (95% C.I.)	p-value	No illuminator (95% C.I.)	Illuminator use (95% C.I.)	p-value
Stride length (m)	0.96 ± 0.64 (0.71–1.23)	0.98 ± 0.55 (0.75–1.22)	0.94	0.85 ± 0.44 (0.59–1.19)	0.75 ± 0.47 (0.55–1.09)	0.79
Gait speed (m/s)	0.74 ± 0.98 (0.40–1.15)	0.63 ± 0.73 (0.36–0.95)	0.51	0.46 ± 0.45 (0.24–0.83)	0.41 ± 0.52 (0.20–0.79)	0.79
Cadence (step/min)	37.38 ± 15.22 (31.26–43.92)	34.11 ± 14.24 (28.62–39.87)	0.04*	46.33 ± 16.86 (34.18–55.47)	42.43 ± 5.40 (39.00–46.13)	0.16
Stance phase (%)	78.51 ± 9.21 (74.56–82.34)	78.77 ± 10.11 (74.55–82.78)	0.79	72.35 ± 11.13 (65.59–80.00)	68.21 ± 16.60 (56.63–76.41)	0.87
Affected swing phase (%)	21.51 ± 9.21 (17.67–25.45)	21.24 ± 10.11 (17.23–25.45)	0.79	27.66 ± 11.13 (20.01–34.41)	31.80 ± 16.59 (23.61–43.39)	0.87
Affected single-support phase (%)	14.44 ± 7.51 (11.55–17.74)	13.74 ± 5.96 (11.29–16.35)	0.35	19.45 ± 5.62 (16.38–23.35)	17.38 ± 3.62 (14.99–19.67)	0.09
Double-support phase (%)	18.64 ± 12.22 (14.07–24.02)	19.20 ± 11.92 (14.74–24.10)	0.46	15.93 ± 9.57 (10.23–22.17)	18.29 ± 7.37 (13.44–22.95)	0.67
Heel-strike angle (degree)	1.10 ± 5.19 (-1.05–3.15)	4.56 ± 6.39 (1.90–7.31)	< 0.01*	-1.73 ± 7.07 (-6.39–2.61)	2.39 ± 4.82 (-0.66–5.52)	0.05*
Toe-off angle (degree)	-9.53 ± 13.77 (-15.66–-4.47)	-10.05 ± 12.50 (-15.34–-5.43)	0.47	-15.91 ± 9.74 (-22.51–9.93)	-14.61 ± 6.56 (-19.35–10.64)	0.83

Notes: *$p < 0.05$.
Heel-strike angle: angle between calcaneus and the ground at the time of heel strike during a gait cycle; toe-off angle: angle between toes and the ground at the time of toe-off during a gait cycle.

with laser. We observed that the heel-strike angle increased significantly with the use of quad-cane with laser, from $0.34 \pm 5.76^\circ$ to $4.00 \pm 6.01^\circ$ ($p = 0.02$). However, all of the other parameters of gait cycle we measured, including the stride length, the gait speed, the cadence, percentage of the stance phase, swing phase, single-support phase, and double-support phase in a gait cycle, and the toe-off angle, showed no significant change with the use of quad-cane with laser.

Table 3 presents the immediate effects of parameters of gait cycle in stroke patients who use AFOs and those who do not use AFOs after using the quad-cane with laser. For stroke patients walking without AFOs, no significant change except that the heel-strike angle increased from $-1.73 \pm 7.07^\circ$ to $2.39 \pm 4.82^\circ$ ($p = 0.05$) was noted between parameters of gait cycle with and without the use of illuminator quad-cane. For patients with strokes using AFOs, after using the illuminator quad-cane, the cadence decreased from 37.38 ± 15.22 steps/min to 34.11 ± 14.24 steps/min ($p = 0.04$), and the heel-strike angle increased from 1.10 ± 5.19 to $4.56 \pm 6.39^\circ$ ($p < 0.01$). Both changes were statistically significant.

Discussion

The purpose of this study was to investigate the immediate effects of an auxiliary illuminator on the gait parameters in patients with subacute and chronic stroke. After using a quad-cane with laser, we observed a significant increase in the heel-strike angle, regardless of using with AFO or not. We also found a significant decrease of cadence after using quad-cane with laser in patients ambulating with AFO. The other parameters we measured during a gait cycle (i.e., stride length, gait speed, duration of stance phase, duration of swing phase, duration of single support and double support, and toe-off angle) revealed no significant change before and after the using of quad-cane with laser.

With the use of auxiliary illuminator to provide visual feedback, stroke patients would use their vision to correct the steps of the affected limbs. By following the guidance of therapist to move their hemiplegic lower extremity to step on the cross made by two laser beams, participants might not only reduce external rotation in the tibia of the affected leg but also reduce the use of circumduction gait, thereby increasing the heel-strike angle. In able-bodied older people, the ankle begins the gait cycle in a neutral position at the time of initial contact. There is rapid plantar flexion to approximately 10° of plantar flexion that occurs during the heel strike. Then the angle gradually dorsiflexed to a peak of 10° just before pre-swing.[24] However, lack of dorsiflexion in swing phase and at heel strike is a commonly reported kinematic deviation in people with hemiplegic stroke.[25,26] To compensate this, stroke patients might use compensate gait pattern like abducting the swing hip, laterally flexing the trunk towards the unaffected side, and decreasing peak knee flexion.[25] A study of hemiplegic individuals conducted by Lehmann *et al.* indicated that an ankle fixed in plantarflexion may cause difficulty in limb clearance during swing.[27] The increase of ankle dorsiflexed angle caused the knee to be more flexed and anterior to the ground reaction force, resulting in a decreased peak knee extension angle and peak knee flexion moment.[28] Therefore, the significant increase of heel-strike angle after using quad-cane with laser might decrease the hyperextension knee moment of the affected limb.

For able-bodied individuals, the heel remains the sole source of support for the first 6–10% of the gait cycle and the loading response phase typically occurs during the first 10% of the gait cycle.[29] However, the loading response period was prolonged, ranging from 10% to 17% of the cycle, among stroke patients.[30,31] Positioning the ankle in slight dorsiflexion has been shown to reestablish the heel as the initial contact base of support[32] and also relieve force on the heel during the loading response phase.[31] Since the heel-strike angle increased significantly by using the quad-cane with laser, stroke patients could put less pressure on the heel and propulsion more smoothly from initial contact to foot flat.

The participants in this study were stroke patients after the acute stage with a mean duration 33.83 months from the onset to the date of experiment, which means that all the participants were used to the gait they used and it was difficult to correct by just small numbers of practice.[33] Since we did only twice measurement (without and with the quad-cane with laser) without any practice before, the change of parameters of the gait cycle might solely contribute to the quad-cane with laser. It was the strength of this study when it comes to the immediate effect but a critical weak point as for the clinical effectiveness of the quad-cane with laser in gait parameters since the change of ambulation pattern might take a longer time and needs massive practice.

For a normal adult walking at a comfortable gait speed, the stance phase and swing phase accounts for about 62% and 38% of the entire gait cycle, respectively.[6,27] However, hemiplegic stroke patients presented asymmetrical postures and movements and they also shifted center of gravity to the sound side during walking, causing the ratio of the stance phase in the gait cycle to increase.[34,35] We did not observe significant decrease of the duration of the affected swing phase nor significant increase of the duration of double-support phase with the use of the auxiliary illuminator. Since patients after acute stroke get used to the compensate gait pattern, the immediate influences on the ratio of swing and stance phase by quad-cane with laser might be little. Whether using the quad-cane with laser could improve symmetry of swing and stance phase ensured the future larger study with an adequate training period.

Since the participants were unfamiliar with the use of the quad-cane with laser and they had to notice the visual cue of the illuminator and to listen to and understand the commands of therapist to move, we assumed that there might be a decrease in stride length, cadence and walking velocity. However, we noticed insignificant changes in these parameters with the use of quad-cane with laser. Therefore, we were assured that once the participants got used to the training process and the quad-cane with laser, they could walk at usual gait speed or even faster.[36] However, future larger studies are warranted to prove this assumption.

Subgroup analysis of our study showed that not only the increase of the heel-strike angle but also the decrease of cadence reached significantly statistical differences in stroke patient with AFOs' use. Studies had proved that in stroke patients with drop foot, the use of AFO has positive effects on functional ambulation and gait parameters, such as increased walking speed, cadence, ankle dorsiflexion at initial contact.[31,37,38] Therefore, the immediate significant increase of heel-strike ankle might contribute to the use of quad-cane with laser. Stroke patients with more severe hemiplegic extremities might present with drop foot and they usually need AFO of the affected leg for functional ambulation. Since our participants were encouraged to move their affected leg as far as possible to or even over the cross made by the two laser beams, they had to raise their affected leg high enough to get an adequate toe clearance. Patients ambulating with AFOs had more inability to generate a sufficiently large dorsiflexor muscle moment[25] and, therefore, the cadence decreased with the use of quad-cane with laser.

Despite its contributions, our study has several limitations. First, the sample size of our study was relatively small, especially for the stroke patients who do not use AFOs in the subgroup analysis. Small numbers of participants made this study less representative and made the statistical analysis more difficult to reach significance. Second, the subjects were recruited randomly in a single medical center in Southern Taiwan and all the patients were in the subacute and chronic stage, so the results might be only generalizable to similar populations, even though the basic characteristics (except for the ration of ischemic and hemorrhagic stroke) of our participants were similar to data found in the national survey in Taiwan by National Health Insurance Research Database. It is necessary to consider increasing the number of enrollment cases in the acute stage of stroke and perform blind randomized group experiments. Third, we could only measure stride length rather than step length by RehaWatch®. This disadvantage of the device made it difficult for us to evaluate the symmetry of the gait and to assess the immediate effect of quad-cane with laser on the sound and the affected lower extremities. Fourth, since participants in this study had performed the controlled condition first (without quad-cane with laser) and then the experimental condition (with the quad-cane with laser), the order effect may have contributed to the immediate change in parameters of gait cycle. Fifth, the minimal required estimated sample number was 15 for this study. The participants who did not use AFOs during ambulation were only eight and would be insufficient to draw the interpretation in the subgroup analysis. Last, we only assessed the immediate effect on parameters of gait cycle with the use of assistive device with auxiliary illuminator. Whether long-term use of the walking assist device with auxiliary illuminator for stroke patients can improve balance, daily living function and gait pattern of the lower limbs should also be investigated to verify the effectiveness of the prolonged use.

Conclusion

The results of this study showed that patients after acute stroke had an immediate change in heel-stroke angle by using a quad-cane with laser during

ambulation, which might help the patients to reduce knee hyperextension moment and lessen the pressure of heel at loading phase, and even make the propulsion from initial contact to foot flat more smooth. Larger and nation-wide prospective blinded studies with long-term follow-up are warranted to assess the clinical effectiveness of this promising, portable, and easy-to-use assistive device.

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Conflict of Interest

The authors have no conflicts of interest to declare.

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Author Contributions

W. Y. Huang, M. H. Li and P. T. Hsu were responsible for research conception and design of the study. W. Y. Huang, S. H. Tuan, X. Y. Liu and P. T. Hsu were involved with analysis/interpretation of data, and critical revision of the manuscript for important intellectual content. All authors were involved in the acquisition of data, drafting the manuscript, and approval of the manuscript to be published.

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Walking velocity and modified rivermead mobility index as discriminatory measures for functional ambulation classification of chronic stroke patients

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Background: The cut-off values of walking velocity and classification of functional mobility both have a role in clinical settings for assessing the walking function of stroke patients and setting rehabilitation goals and treatment plans.
Objective: The present study investigated whether the cut-off values of the modified Rivermead Mobility Index (mRMI) and walking velocity accurately differentiated the walking ability of stroke patients according to the modified Functional Ambulation Category (mFAC).
Methods: Eighty two chronic stroke patients were included in the study. The comfortable/maximum walking velocities and mRMI were used to measure the mobility outcomes of these patients. To compare the walking velocities and mRMI scores for each mFAC point, one-way analysis of variance and the post-hoc test using Scheffe's method were performed. The patients were categorized according to gait ability into either mFAC = VII or mFAC ≤ VI group. The cut-off values for mRMI and walking velocities were calculated using a receiver-operating characteristic curve. The odds ratios of logistic regression analysis (Wald Forward) were analyzed to examine whether the cut-off values of walking velocity and mRMI can be utilized to differentiate functional walking levels.
Results: Except for mFACs III and IV, maximum walking velocity differed between mFAC IV and mFAC V ($p < 0.01$), between mFAC V and mFAC VI ($p < 0.001$), and between mFAC VI and mFAC VII ($p < 0.05$).

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The cut-off value of mRMI is > 26.5 and the area under the curve is 0.87, respectively; the cut-off value for comfortable walking velocity is > 0.77 m/s and the area under the curve is 0.92, respectively; also, the cut-off value for maximum walking velocity is > 0.92 m/s and the area under the curve is 0.97, respectively. In the logistic regression analysis, the maximum walking velocity (> 0.92 m/s, OR = 22.027) and mRMI (> 26.5 scores, OR = 10.283) are able to distinguish mFAC = VII from mFAC $\leq$ VI.
Conclusion: The cut-off values of maximum walking velocity and mRMI are recommended as useful outcome measures for assessing ambulation levels in chronic stroke patients during rehabilitation.

Keywords: Discriminatory factors; modified Functional Ambulation Category; modified Rivermead Mobility Index; stroke; walking speed.

Introduction

The walking function of stroke patients is closely related to mobility, walking velocity, cardiovascular endurance, dynamic balance, motor skill, and muscular strength in the lower limb of the affected side.[1,2] Recovery of functional mobility and walking function is the priority of rehabilitation after stroke.[3] Therefore, in clinical settings physical therapists assess the gait and mobility of stroke patients using standardized assessments such as walking velocity[4] and the modified Rivermead Mobility Index (mRMI).[5]

The modified Functional Ambulation Category (mFAC), which uses a seven-point Likert scale, is a tool for clinical assessment of walking ability in stroke patients that uses a Functional Ambulation Classification system. The mFAC has been shown to have a high correlation ($r = 0.88$–0.90) with walking velocities (comfortable/maximum) and mRMI performance scores.[6] In other words, as the functional gait ability is recovered in stroke patients, the physical measurements of walking velocity and mRMI are increased. In one correlation study,[6] there were significant differences in walking velocity and mRMI scores, as reflected by the mFAC scores between stroke patients (from III to V points) and the independent ambulatory group (VI and VII points). Tsang *et al.*[7] found significant differences in average walking velocity between different mFAC scores (III–VII) of 62 stroke patients, and they determined that mFAC could accurately classify the ambulation levels. However, results from these studies focused on only the statistical differences in mRMI and walking velocities in stroke patients. It is not clear whether the mFAC score may be determined based only on values of mRMI and walking velocities.

Previous studies proposed the cut-off values of walking velocities for community ambulation. Three levels of community ambulation have been classified with the following thresholds: most limited community walkers (25 m/min), limited community walkers (35 m/min), and community walkers (48 m/min).[8] Previous literature determined cut-off values of community ambulation levels according to the walking velocity (indoor ambulation: > 0.4 m/s, limited community ambulation: 0.4–0.8 m/s, and community ambulation: > 0.8 m/s).[9] The cut-off values of walking velocity and classification of functional mobility both have a role in clinical settings for assessing the walking function of stroke patients and setting rehabilitation goals and treatment plans.

The aim of this study was to quantitatively categorize two different mFAC groups using cut-off values of walking velocity and mRMI. This study investigated whether the cut-off values of walking velocity and mRMI can be discriminatory measures of functional ambulation for stroke patients categorized into two groups, mFAC = VII and mFAC $\leq$ VI. In this study, we used the definitions of discrimination suggested in previous literature.[10] Lord *et al.*[10] stated that when the community-walking ability was classified into four levels, the walking velocity increased as the level of gait ability increased, and the walking velocity decreased as the level of gait ability decreased. As a result, walking velocity was deemed to be a suitable measurement for discriminating the four levels of community walking categorized by a self-questionnaire. The hypotheses of this study are as follows: (1) there will be significant differences in walking velocities and mRMI in different mFAC categories, (2) there will be significant differences in walking velocities and mRMI between the two groups, and (3) the cut-off values of walking velocity and mRMI will be discriminatory indicators for mFAC.

Methods

Participants

This study was a cross-sectional investigation conducted with 91 patients with chronic hemi-paralysis caused by stroke. Our participants consisted of both inpatients and outpatients at *M* hospital. The study design was blinded for assessment and intention-to-treat analysis. Participants had cognitive function scoring of no less than 23 points on the Mini-Mental State Examination-Korean version (MMSE-K).[11] The participants did not have a lower motor neuron lesion or an orthopedic disease in the lower limbs. Ninety one chronic stroke patients initially enrolled on the basis of these inclusion criteria. General characteristics collected via hospital records and interviews included age, time since onset, diagnosis, location of paralysis, and MMSE-K scores. The procedures of this study were approved by Konyang University Institutional Review Board (IRB Approval No. 2017-066) and the participants signed the informed consent form prior to study participation.

Assessment procedures

Outcome assessment was performed by two physical therapists with more than 15 years of experience (SH, DS) in stroke treatment and diverse evaluation methods including the study's evaluation methods. The assessments were completed within 30 min, and the investigators provided a break for all participants between the two assessments to minimize the effect of fatigue.

Measures

The outcome measures in this study were composed of two standardized mobility assessments including the mFAC and a seven-point scale for classifying the gait ability of participants. The mobility measures were: (1) comfortable walking velocity (CWV, m/s) and maximum walking velocity (MWV, m/s), as measured by the modified 5-m Ambulation Velocity Test, which includes a 2-m acceleration and deceleration interval, for a total distance of 9 m, which helped minimize the necessary space and lessened the mental burden and stress of participants.[12] All subjects were asked to stop at the marked end point, and were instructed to walk as fast as they could three times while maintaining the safety. The examiner recorded the time taken to walk from the end of the 2-m acceleration mark to the start of the 2-m deceleration mark. (2) The mRMI score is determined based on eight questions about mobility. The inter-rater reliability of mRMI [intra-class correlation coefficient (ICC) = 0.98][5] and test–retest reliability (ICC = 0.99) have been established in stroke patients.[7]

To determine each participant's ambulation ability, the primary physical therapist (SH) evaluated the mFAC[13] with the following criteria. Depending on the need for physical assistance, ambulation ability was scored as I point (unable to perform ambulation but able to maintain sitting position for 1 min with assistance, or unable to keep the position for 1 min without hand or back support); II points (unable to perform ambulation but able to maintain sitting position for 1 min without supporting self with hands or back support); III points (need someone to provide constant and reliable assistance for ambulation); IV points (need someone to provide constant or intermittent assistance for ambulation); V points (need verbal cues and supervision for ambulation); VI points (able to perform indoor ambulation on level ground); and VII points (able to perform outdoor ambulation). The mFAC test–retest reliability (concordance rate = 93%, weighted kappa coefficient = 0.97) was reported in stroke patients.[7]

The participants were assigned to groups according to walking levels using the mFAC. The mFAC is a seven-point scale that classifies the walking function level. In the current study, functional gait ability (i.e., outdoor gait ability) was defined depending on whether a patient could perform activities such as climbing the stairs, walking on uneven levels, etc.; the effect of this ability on social outcomes was not considered. If the participants could perform outdoor ambulation, they were categorized into an mFAC = VII group (high-level ambulation group, HG). If the tasks could not be performed, the categorization was mFAC $\leq$ VI (low-level ambulation group, LG). In this study, the participants' functional walking levels were separated into two groups with mFAC = VII points (HG) and $\leq$ VI points (LG).[14] All the participants were unaware of their classification.

Statistical analysis

Descriptive statistics were computed for data, including the data regarding general characteristics,

mFAC points, mRMI score, and comfortable and maximum walking velocities. For comparing the walking velocities and mRMI scores for each mFAC point, we used one-way analysis of variance and performed the post-hoc test using Scheffe's method. The Mann–Whitney test was conducted to compare the walking velocities and mRMI scores of HG and LG. For the comparative analysis of effect size, Cohen d was utilized. The cut-off value was produced by using the receiver-operating characteristic curve (ROC curve) for the differentiation of walking velocity and mRMI for functional walking levels. In the area under the ROC curve (AUC), $0.5 < AUC \leq 0.7$ indicates lower precision, $0.7 < AUC \leq 0.9$ indicates mid-level precision, $0.9 < AUC < 1.0$ indicates high precision, and $AUC = 1.0$ indicates complete test.[15] With respect to the cut-off values of walking velocity and mRMI, the odds ratio (OR) in logistic regression analysis (Wald Forward) was used to estimate the discriminative validity of functional walking levels. All data were analyzed using IBM SPSS Statistics version 20.0 (IBM Corp., Armonk, NY, USA) and the statistical significance level was set at $\alpha = 0.05$.

Table 1. General characteristics.

Variable	Value (s)
Gender: Male/Female (n)	51/31
Age (years): Mean (SD)	59.09 (11.74)
Diagnosis: infarct/hemorrhage (n)	58/24
Hemiplegic side: Right/Left (n)	44/38
Duration (month): Mean (SD)	16.43 (12.24)
MMSE-K (score): Mean (SD)	26.20 (1.54)
Mobility status: (n)	
Unaided	34
Single-point cane	33
Quadripod	12
Walker	3
mFAC (point): Mean (SD)	5.35 (1.35)
mFAC III/IV/V/VI/VII (n)	10/13/18/20/21
mRMI (score): Mean (SD)	26.32 (6.20)
Comfortable walking velocity (m/s): Mean (SD)	0.59 (0.27)
Maximum walking velocity (m/s): Mean (SD)	0.75 (0.36)

Note: SD: Standard deviation, MMSE-K: Mini Mental State Examination-Korean version, mFAC: modified Functional Ambulation Category, and mRMI: modified Rivermead Mobility Index.

Results

Subjects' characteristics

Six participants dropped out during the examination period due to a deteriorating health condition or discharge from the hospital. Ultimately, 82 participants were included in the study analysis. The general characteristics of the participants are provided in Table 1. The participants were within the mFAC range of III–VII.

Walking velocity and mRMI in different mFAC categories

The walking velocities and mRMI scores of 82 chronic patients of mFAC categories III–VII were measured (see Table 2). The mean CWV increased from 0.17 m/s [standard deviation (SD): 0.4] for mFAC III to 0.86 m/s (SD = 0.15) for mFAC IV, 0.50 m/s (SD = 0.11) for mFAC V, 0.75 m/s (SD = 0.08) for mFAC VI, and 0.86 m/s (SD = 0.15) for mFAC VII. In addition, the mean MWV increased from 0.26 m/s (SD = 0.6) for mFAC III to 0.38 m/s (SD = 0.04) for mFAC IV, 0.60 m/s

Table 2. Walking velocities and mRMI scores of patients of different mFAC categories.

	mFAC = III (n = 10)	mFAC = IV (n = 13)	mFAC = V (n = 18)	mFAC = VI (n = 20)	mFAC = VII (n = 21)
Comfortable velocity (m/s)	0.17 ± 0.04	0.30 ± 0.01	0.50 ± 0.11[a]	0.75 ± 0.08[b]	0.86 ± 0.15[c]
Maximum velocity (m/s)	0.26 ± 0.06	0.38 ± 0.04	0.60 ± 0.12[a]	0.88 ± 0.11[b]	1.20 ± 0.21[c]
mRMI (score)	17.0 ± 3.68	20.54 ± 2.66	27.56 ± 3.65[a]	28.55 ± 3.31	32.33 ± 3.74[c]

Note: mRMI: modified Rivermead Mobility Index. [a]Significant difference between mFACs IV and V ($p < 0.01$). [b]Significant difference between mFACs V and VI ($p < 0.001$). [c]Significant difference between mFACs VI and VII ($p < 0.05$). p was based on one-way ANOVA (post-hoc test by Scheffe's method).

Table 3. Comparison of walking velocities and mRMI scores in HG (mFAC = VII) and LG (mFAC ≤ VI).

Variable	Mean ± SD (min, max)		Z	p-Value	Cohen d
	HG (mFAC = VII, $n = 21$)	LG (mFAC ≤ VI, $n = 61$)			
mRMI	32.33 ± 3.74 (26, 40)	24.66 ± 5.63 (13, 34)	5.05	< 0.001	1.23
Comfortable velocity (m/s)	0.87 ± 0.15 (0.66, 1.31)	0.49 ± 0.23 (0.12, 0.98)	5.70	< 0.001	1.39
Maximum velocity (m/s)	1.20 ± 0.21 (0.87, 1.54)	0.60 ± 0.26 (0.19, 1.23)	6.36	< 0.001	1.65

Note: mRMI: modified Rivermead Mobility Index; mFAC: modified Functional Ambulation Category; HG: high-level ambulation group (mFAC = VII); and LG: low-level ambulation group (mFAC ≤ VI).

Table 4. Sensitivity and specificity of walking velocity and mRMI for discriminating functional walking levels.

Variable	Cut-off value	AUC (95% CI)	p-Value	Sensitivity	Specificity
mRMI (score)	> 26.50	0.87 (0.79, 0.95)	< 0.001	95% (20/21)	62% (38/61)
Comfortable velocity (m/s)	> 0.77	0.92 (0.86, 0.98)	< 0.001	90% (19/21)	88% (54/61)
Maximum velocity (m/s)	> 0.92	0.97 (0.93, 1.00)	< 0.001	85% (18/21)	93% (57/61)

Note: mRMI: modified Rivermead Mobility Index; and AUC: area under the receiver-operating characteristic curve.

(SD = 0.12) for mFAC V, 0.88 m/s (SD = 0.11) for mFAC VI, and 1.20 m/s (SD = 0.21) for mFAC VII. There were significant differences in both velocities between patients of mFAC IV and those of mFAC V ($p < 0.01$), between patients of mFAC V and those of mFAC VI ($p < 0.001$), and between patients of mFAC VI and those of mFAC VII ($p < 0.05$).

The mean mRMI score increased from 17.0 (SD = 3.68) for mFAC III to 20.54 (SD = 2.66) for mFAC IV, 27.56 (SD = 3.65) for mFAC V, 28.55 (SD = 3.31) for mFAC VI, and 32.33 (SD = 3.74) for mFAC VII. There were statistically significant differences in the mRMI scores between patients of mFAC IV and mFAC V ($p < 0.001$) and between those of mFAC VI and mFAC VII ($p < 0.05$).

Comparison of mobility outcomes between groups

The results of the mRMI performance score and comfortable and maximum velocities are shown in Table 3. Between the HG and LG groups, there were significant differences in mRMI scores, CWVs, and MWVs (all $p < 0.001$).

Cut-off value, AUC, sensitivity, and specificity

The mRMI cut-off value, sensitivity, and specificity were > 26.5 scores, 95%, and 62%, respectively. The CWV cut-off value, sensitivity, and specificity for functional walking distinction were > 0.77 m/s, 90%, and 88%, respectively. The MWV cut-off value, sensitivity, and specificity were > 0.92 m/s, 85%, and 93%, respectively (Table 4). With regression coefficients, the mRMI value (> 26.5 scores, OR = 10.283) was able to distinguish between the mFAC categorizations (HG and LG) (Table 5). However, MWV (> 0.92 m/s, OR = 22.027) was the most effective value for discriminating between LG (mFAC ≤ VI) and HG (mFAC = VII).

Table 5. Discriminatory measures analysis of cut-off values of walking velocity and mRMI for functional ambulation.

Score	Regression coefficient	Wald	Odds ratio	95% CI	p-Value
Comfortable velocity > 0.77 m/s	1.40	0.98	4.07	0.25–66.00	0.323
mRMI > 26.5	2.33	5.60	10.28	1.49–70.92	0.018
Maximum velocity > 0.92 m/s	3.09	4.80	22.02	1.39–350.41	0.028

Note: mRMI: modified Rivermead Mobility Index.

Discussion

This study investigated whether the cut-off values of mRMI and walking velocities can differentiate the mFAC scores of stroke patients who were divided into two groups based on the mFAC classification of their functional walking levels. As expected, our results found that there were significant differences between HG and LG in the mean ± SD mRMI score (32.33 ± 3.74 and 24.66± 5.63), CWV (0.87 ± 0.15 m/s and 0.49 ± 0.23 m/s), and MWV (1.20 ± 0.21 m/s and 0.60 ± 0.26 m/s). Our study demonstrated that the cut-off values of mRMI (26.5 score, OR = 10.283), CWV (0.77 m/s, OR = 4.07), and MWV (0.92 m/s, OR = 22.03) accurately discriminated mFAC scores between patients of HG (mFAC = VII) and LG (mFAC ≤ VI). The MWV and mRMI were more suitable assessments to classify walking function levels than CWV. The cut-off values of MWV (0.92 m/s, OR = 22.03) had the highest distinguishing power among the assessments evaluated. Additionally, the walking velocities and modified mRMI scores of patients of different mFAC categories were investigated, with particular focus on the outcomes which showed that MWV could differentiate between patients of mFAC IV and those of mFAC V, between patients of mFAC V and those of mFAC VI, and between patients of mFAC VI and those of mFAC VII with robust statistical power.

It is noteworthy that the CWV and MWV were significantly different between mFAC IV and mFAC V, between mFAC V and mFAC VI, and between mFAC VI and mFAC VII. This result showed that walking velocities may be the discriminatory variable for chronic stroke patients belonging to an mFAC higher than IV. However, no variable was significantly different between mFAC III and mFAC IV. This failure to identify the low mFAC is a consistent limitation in the previous study,[7] which reported the walking velocities of acute stroke patients of mFAC categories ranging from III to IV from different hospitals. The small number of stroke patients included in mFAC III and mFAC IV may account for these results compared to the results observed for patients of other categories. Overall, all variables might not be sensitive to differentiate between mFAC III and mFAC IV in the chronic stroke patients.

The rationale for the score of VII as the cut-off value of the mFAC score is based on the probability of community ambulation without falling. Our categories emphasized reduced ambulation, especially outdoors, as that correlates to a greater factor of debilitation based on a study of 40 people with stroke.[16] Therefore, we decided that the achievement of walking indoors with/without assistance versus walking independently outdoors is the best criteria for defining the overall gait ability (such as climbing stairs, walking on uneven levels, etc., and it was not extended to the social outcome).

Our findings were similar to those of preceding studies. The mean walking velocity within the different mFAC categories was shown to have an increasing trend from mFAC III (0.11 m/s, SD = 0.03) to mFAC IV (0.17 m/s, SD = 0.07), mFAC V (0.30 m/s, SD = 0.13), mFAC VI (0.70 m/s, SD = 0.29), and mFAC VII (0.82 m/s, SD = 0.19), in a study of 62 acute stroke patients. In another study[6] which examined the reliability and validity of mFAC, the mRMI score and walking velocities within each mFAC category were reported to be significantly different. As the mFAC improved from III to V, the average walking velocities (comfortable and maximum) increased from 0.16 m/s and 0.25 m/s in mFAC III to 0.50 m/s and 0.58 m/s in mFAC V, with enhancement of mRMI demonstrating functional mobility. Likewise, this trend was also observed between 0.76 m/s and 0.89 m/s in mFAC VI and between 0.88 m/s and 1.12 m/s in mFAC VII, respectively.[6]

Focusing on sensitivity and specificity, the mRMI showed a sensitivity of 95%, corresponding to the probability of dividing those with mRMI of > 26.5 among 21 participants in the HG, and a specificity of 62%, corresponding to the probability of correctly classifying those with mRMI of ≤ 26.5 among 61 participants in the LG. On the other hand, MWV showed higher specificity (93%) than mRMI, and CWV showed high accuracy in both sensitivity (90%) and specificity (88%). If a stroke survivor has mRMI of > 26.5, CWV of > 0.77 m/s, and MWV of > 0.92 m/s, a physical therapist will consider that the person is able to ambulate outdoors (high walking level), it helps to confirm the level of walking function. We considered that only the results of sensitivity and specificity were difficult to determine the implications. However, it has been reported that higher ambulation velocity leads to better mobility, and stroke survivors' ambulation activities are almost unlimited if they can ambulate freely.[10,13,17]

According to the cases of Tsang *et al.*[7] of initial stroke patients' hospitalization and discharge, the AUC level of mRMI was identified similarly (AUC = 0.79), and the cut-off value of > 20 was slightly inconsistent with the present findings. The mean score (SD) of mRMI was 26.62 (6.2) in chronic stroke patients in this study, and was 20.6 (9.3) at admission in acute stroke patients in Tsang *et al.*'s[7] prospective study. The inconsistent findings might be explained by the fact that there were differences in the post-stroke period of the participants and differences in study design. In Tsang *et al.*'s study,[7] the assessments were performed in hospital settings with assistance and monitoring, without any actual experience of community ambulation. However, our study included outpatient experiences in community ambulation.

Our results of walking velocities are consistent with those of previous studies. An *et al.*[18] reported that walking velocity (OR = 9.20) was the most powerful determinant variable of community walking among several assessments including the Berg Balance Scale, walking distance, and the Fugl–Meyer assessment. A previous study stated that walking velocity is a strong factor for predicting the level of community walking.[10] In accordance with previous studies, the results of this study suggested that maximum walking velocity (OR = 22.03) is a superior clinical assessment to discriminate between different categories of functional ambulation (HG and LG).

The research findings by Lord *et al.*[10] suggest that the FAC does not reflect the real community ambulation levels. However, Hill *et al.*[19] suggested that to achieve a successful gait within the community, at least FAC = VI, the equivalent of mFAC = VII, is necessary. The use of only mFAC is not sufficient to assure community ambulation ability. The mRMI describes the patient's mobility to perform an activity,[5] and walking velocity (comfortable/maximum) is a valid measure for identifying therapy effectiveness in stroke patients.[10] These results support the findings of this study, which suggest the physiotherapist can be better informed of the stroke patients' prognosis for functional walking levels during rehabilitation based on the walking velocity scores compared to mFAC alone.

Study limitations

Despite the clear findings of this study, it has several unavoidable limitations. This study supports the applicability of dichotomized walking velocity and mRMI score in chronic stroke patients. However, the application of walking velocity and mRMI is limited to acute stroke patients. In addition, although the participants were from subsidy-supported rehabilitation hospitals, their functional gait ability varied, and they required assistive tools or support for walking. This requirement may be associated with a fall history, which could lead to a loss of confidence to walk actively.[20] Therefore, to advance and validate our results, a study should be conducted in the future reporting on factors pertaining to gait ability and the need to identify a clinical variable that can especially discriminate between patients of mFAC III and those of mFAC IV.

Conclusion

In conclusion, this study demonstrated that the cut-off values of walking velocity and mRMI are able to discriminate between two groups within mFAC (HG and LG). As these measures of mobility are easy to assess in clinical settings, the dichotomized walking velocity and mRMI are useful for examining the walking ability in a population with chronic stroke. Future research is required to identify the cut-off values of additional measures of mobility in populations with neurological disorders.

Conflict of Interest

The authors declare no conflicts of interest.

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Author Contributions

All the authors contributed to the conception and design of the study, data analysis, and interpretation. Ji Young Lim, Seung Heon An, and Dae-Sung Park drafted the manuscript and revised it critically and provided approval for the submission to publication.

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Research Paper

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Effects of combination therapy and infrared radiation on pain, physical function, and quality of life in subjects with knee osteoarthritis: A randomized controlled study

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Background: Knee osteoarthritis (KOA) is a common degenerative articular disease that causes disability and poor quality of life (QoL) of the individuals. Electrotherapeutic agents such as therapeutic ultrasound (US), interferential current (IFC), and infrared radiation are used in the treatment. It is not clear which of these agents is the best in improving these variables.
Objective: The study aimed to compare the effects of the combined application of US and IFC therapies and infrared radiation on pain, functional activities, and QoL in people with KOA.
Methods: In a randomized controlled study, 60 participants were randomized into two groups, the combination therapy group (CTG) and the infrared radiation group (IRG). Each group received 15-min treatment three times per week for 12 weeks. The visual analog scale (VAS) was used to assess the pain, Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) for functional activities and the Short Form Health Survey questionnaire for QoL.
Results: Participants in the CTG had a significant ($p < 0.05$) reduction in pain and significant ($p < 0.05$) improvement in functional activities and QoL compared to the IRG.

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Conclusion: The results of this study support the use of the combination of IFC and US therapies to reduce pain and improve function and QoL for KOA patients.

Keywords: Combination therapy; interferential current therapy; infrared radiation; knee osteoarthritis; therapeutic ultrasound.

Introduction

Osteoarthritis (OA) is a progressive degenerative articular disease characterized by marginal osteophyte formation, destruction of joint cartilage, and subchondral bone changes.[1,2] Clinical symptomology includes joint pain, loss of joint functions, and limitation of joint range of motions.[3] OA mostly affects weight-bearing joints such as knee and hip. The disease rate increases with increase in age and obesity, with arthritis pains and dysfunction affecting patient's quality of life (QoL).[4] OA is one of the commonest causes of disability among elderly individuals.[5] It has been shown that 50% of people over the age of 65 years have radiological features of OA, with roughly 10% of men and 18% of women suffering symptomatic OA.[6]

The aims of knee OA treatment are to reduce pain and improve function or quality of life based on interferential current (IFC) approach.[7] Moreover, drug treatments for the elderly are often limited, producing suboptimal benefits because of comorbidities, polypharmacy, and the associated high risk of side effects of drugs.[7,8] No pharmacological treatments are recommended for the treatment of OA, such as exercises and physical therapy modalities to treat patients with knee OA, in an attempt to limit the side effects of medication. In addition to the use of heat and cold, therapeutic ultrasound (US) and interferential current were also used.[9]

IFC approach is characterized by superimposing of two slightly different medium-frequency currents (4,000 Hz) to form a new medium-frequency current with an amplitude modulation at low frequency (0–250 Hz).[10,11] It has been stated that amplitude-modulated frequency (AMF) is the main electro-analgesic component of IFC.[12] IFC therapy achieves its pain modulation by stimulating afferent large-diameter fibers. Studies have reported IFC therapy's effectiveness in the treatment of painful musculoskeletal problems such as sports injuries; bruising and swelling, low back pain, osteoarthritis, rheumatoid arthritis, and muscular pain.[13–15]

Therapeutic US is one of the most frequently applied electrotherapeutic modalities in orthopedics physiotherapy.[16] It produces thermal effects which increase tissue metabolism, collagen elasticity, and capillary blood flow and reduce skeletal muscle spasm.[17] Therapeutic ultrasound is often used in the management of knee osteoarthritis and it is believed to be effective in enhancing inflammatory response, tissue repair, and is absorbed especially in tissues with high collagen contents.[18] Besides the individual therapeutic effects of ultrasound and interferential current therapies, their combination [i.e., combination therapy (CT)] is more effective than each of them applied separately in eliciting localized analgesia on previously detected painful areas.[19]

Infrared radiation with wavelength range from 750 nm to 1 mm can stimulate the production of nitric oxide (NO), enhancing inflammatory response, tissue repair, and is absorbed especially in tissues with high collagen contents.[29,34] Clinical investigations of the efficacy of OA therapies should include symptoms (such as pain), function, disability, and health-related quality of life (HRQoL).[8,20] Further intensive research focusing on the therapeutic effects of ultrasound, interferential current, and infrared on patients with knee OA is required.[7,20,21] To our knowledge, there have been no reports to date that evaluated the effects of combination therapy and infrared on pain, functional activity, and HRQoL of elderly patients with knee OA. We hypothesized there would be significant difference in the administrations of combination therapy and infrared radiation to improve HRQoL, relieve pain, and improve functional activities in patients with knee osteoarthritis. This study, therefore, is aimed at investigating the differences between the combined application of therapeutic ultrasound and interferential current therapies (combination therapy) and infrared lamp on pain, functional activities, and HRQoL of elderly patients with knee osteoarthritis.

Methods

Participants

Sixty outpatients with knee OA, diagnosed according to the American College of Rheumatology criteria, were recruited.[22] Patients were excluded from the study if they had any knee diseases other than OA. Patients with serious concomitant systemic diseases, patients who had corticosteroid or hyaluronic acid injection in the last one month, and patients with previous history of any electrotherapy contraindications were excluded from the study. Subsequently, patients were made to understand the research protocols, before they were randomly allocated into two groups [combination therapy group (CTG) and infrared radiation group (IRG)].

Design

A prospective randomized controlled clinical trial was used.

Randomization

Patients were allocated to either CTG or IRG. The principle of block randomization was used to assign the patients to the groups, with a block size of four. Participants were allocated to their groups by sealed envelope containing their group assignment, which they opened when they were recruited into the study. One physiotherapist enrolled all the participants, and the other physiotherapist generated the allocation sequence and assigned participants to their groups as shown in the flowchart in Fig. 1.

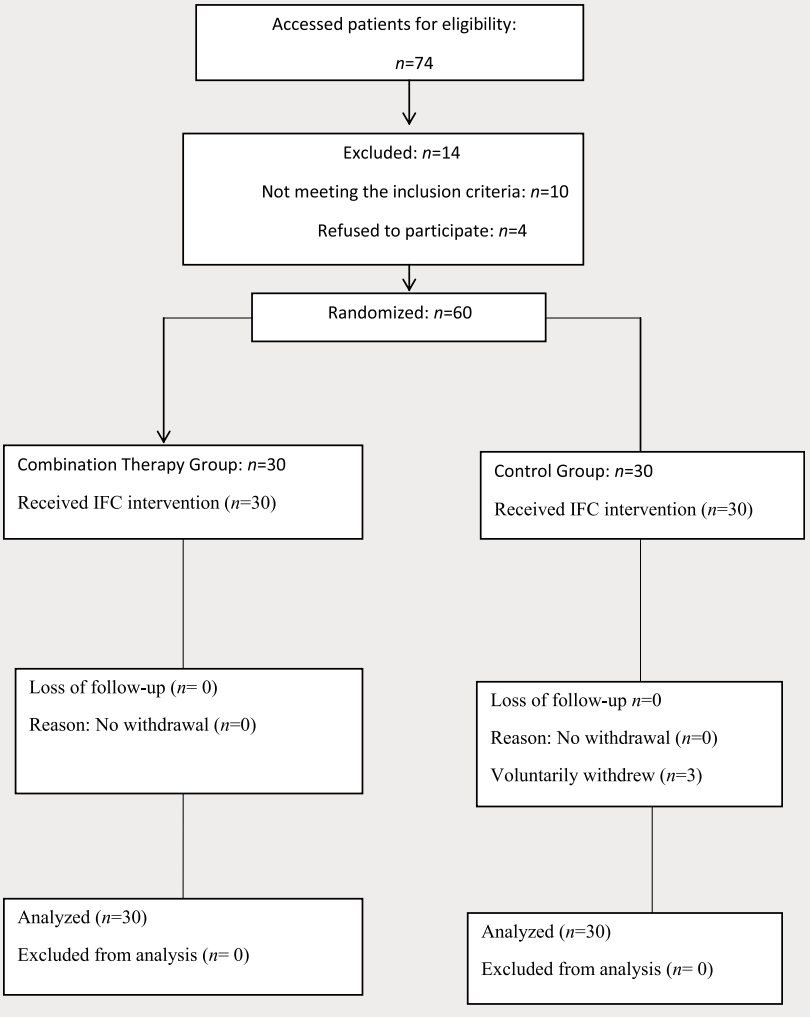

Fig. 1. Consort flowchart depicting the participants from enrolment to analysis.

Measurement

Pain

Pain intensity was assessed on full weight bearing using the visual analog scale (VAS). Participants were asked to indicate the level of their pain between 0 (no pain) and 10 (severe pain), and were instructed not to under- or over-estimate it. The VAS is a single-item numerical scale normally in a straight horizontal or vertical line of fixed length, usually 10 cm (i.e., 100 mm).[23] The ends are defined as the extreme limits of the parameter to be measured with anchor points 0 (no pain) and 10 (maximum pain). It is a highly reliable instrument for measuring pain,[24] with high psychometric values.[25–28]

Functional ability

The Western Ontario and McMaster University Osteoarthritis Index (WOMAC) was used to evaluate the functional ability of the participants, at the baseline and after 12 weeks of treatments. The instrument is an OA-specific outcome measure and self-administered questionnaire with three domains consisting of 24 items. The Likert-scale version of WOMAC was used for the purpose of this study. This scale allows patients to indicate their responses on a five-point scale (0 = none, 1 = mild, 2 = moderate, 3 = severe, and 4 = extreme). The higher the response indicated, the lower the level of perceived health and physical function. Studies have shown high psychometric value for the WOMAC questionnaire. The instrument has been shown to be reliable, valid, and sensitive to changes in clinical symptoms of individuals with knee and hip OA.[29,30]

HRQoL

Participants' health-related quality of life was assessed and recorded using the 36-item Short Form Health Survey (SF-36) questionnaire at baseline and post-treatment. This is a generic HRQoL measurement tool, self-administered, and user-friendly which has been reported as valid and reliable with high internal and external consistencies.[31]

Procedures

The study was conducted at the Outpatient Units of Physiotherapy Departments of Rasheed Shekoni Specialist Hospital, Dutse, Nigeria, and the Federal Medical Centre Birnin Kudu, Jigawa State, Nigeria. The study was approved by the Biomedical Research and Ethics Committee (BREC) of the University of KwaZulu-Natal, Durban, South Africa, and the Ethical Research Committee of the Ministry of Health, Jigawa State, Nigeria. Patients were briefed on the study protocol and signed informed consent to participate in the study which commenced on 1 June 2015 and ended on 31 May 2016.

Participants' height and weight were measured and recorded. Body mass index (BMI) was calculated by dividing weight (kg) by height (m) and recorded. All assessments were conducted at baseline and at the end of 12 weeks of treatment. The primary outcome measures used to assess patients' response to the treatment were WOMAC, SF-36 questionnaire, and the VAS.

Intervention

The CTG

Participants in the combination group underwent electro-diagnosis of the most painful knee area with continuous US (1 MHz; 0.5 W/cm^2) and the IFC (AMF = 100 Hz) at tactile threshold intensity. Treatments were conducted at the intensity of continuous US (1 MHz; 1.5 W/cm^2) applied with 5-cm transducer for 10 min using Sonoplus 920 (Sonicator Plus 920®; Mettler Electronics, CA, USA). Participants were comfortably positioned in supine lying with pillow supported under the treated knee. Ultrasound Transmission Gel (Aqueous gel®) was used as the contact medium. Two adhesive electrodes (6×6 cm^2) were placed opposite to each other (medial and lateral) for deeper penetrations. The US was first turned on, followed by turning of the IFC parameters as mentioned above. Participants were informed that they would experience tingling sensations which should not be unpleasant. Treatments were administered for 10 min three times a week for 12 weeks.

The IRG

Participants in this group were treated with luminous infrared lamp (IRR, Infraphil® 150 W; Philips Electronics, Amsterdam, the Netherlands). The source of the radiation was placed at 60 cm

from the patient's skin for 15 min of a treatment session and the patient was treated three times a week for 12 weeks. Participants were positioned comfortably with knee flexed 20–30° supported with a pillow. Participants were warned that they were expected to feel comfortable "mild warmth" as too much heat could lead to skin burns.

All participants received quadriceps isometric exercises of both knees for 10 min, and were asked to refrain from taking non-steroidal anti-inflammatory drug (NSAIDS) and anti-depressants throughout the study period. However, they also were advised to take acetaminophen in case of unbearable pain and other comorbid medications throughout the study period.

Table 1. Patients' demographic features between CTG and IRG.

Variables	CTG ($n = 30$) M ± SD	IRG ($n = 30$) M ± SD	p-value[a]
Age (years)	65.8 ± 9.21	66.8 ± 8.61	0.153
Weight (kg)	69.29 ± 10.88	70.04 ± 9.66	0.985
Height (m)	1.66 ± 0.08	1.67 ± 0.76	0.780
BMI (kg/m^2)	25.43 ± 3.8	25.54 ± 3.20	0.621
Gender M/F, n (%)	20%/80%	40%/60%	0.146[b]
Gender ratio	4:1	1.5:1	0.145

Note: BMI: Body mass index; M: male; F: female; M: Mean; SD: standard deviation. [a]$p > 0.05$; ND: No data; and [b]$X = 3.842$, $p = 0.146$.

Statistical Analyses

Statistical analyses were conducted with version 21.0 of Statistical Package for the Social Sciences (SPSS Inc., Chicago, IL, USA). The effect size for the sample size calculation was obtained from the previous studies conducted on knee osteoarthritis.[20,32] Based on the data from these studies, it was estimated that a sample size of 30 patients in each study group would achieve a power of 80% to detect an effect size of 0.8 in the outcome measures of interest, assuming a type-I error of 0.05. Preliminary analysis was performed to check for normality, linearity, and homogeneity of variance, covariance, and multicollinearity with no serious violations noted with MAHAL. Descriptive statistics of mean, percentage, and standard deviation were used to describe the data. A one-way between-groups multivariate analysis of variance (MANOVA) was performed to investigate the differences between the combination therapy group and infrared group, four dependent variables were used for pain and physical function, and 10 dependent variables for quality of life. A p-value equal to or less than 0.05 was considered as statistically significant. Furthermore, standardized effect sizes (Cohen's d) with 95% confidence interval (CI) were included.

Results

A total of 63 patients with knee osteoarthritis participated in the study, and were randomized into CTG and IRG. During the study, three patients (one from CTG and two from IRG group) failed to follow up and were not included in the analyses (Fig. 1). Of the 60 participants who completed the study, 42 (70%) were female and 18 (30%) were male, with a mean age of 66.3 ± 8.91 years. Table 1 shows participants' demographic characteristics at the baseline. There was no statistically significant difference in gender, age, and BMI between CTG and IRG at the baseline ($p > 0.05$).

Pain and functional activity scores

At baseline, there was no statistically significant difference between the two groups in terms of pain and functional activities: $F = 0.208$; $p = 0.933$; Wilk's lambda = 0.208; and partial eta-squared = 0.015. The p-value for each dependent variable for the pain and functional activity scores is shown in Table 2.

There was a statistically significant difference between the two groups in terms of pain and functional activities after 12 weeks of intervention: $F = 772.64$; $p = 0.000$; Wilk's lambda = 772.64; and partial eta-squared = 0.983. When the results for the dependent variables were considered separately, using a Bonferroni-adjusted alpha level of 0.012, all the variables were statistically significant as shown in Table 3.

HRQoL

At baseline, there was no statistically significant difference between the two groups in terms of quality of life using SF-36: $F = 1.56$; $p = 0.143$; Wilk's lambda = 0.73; and partial eta-squared = 0.263.

Table 2. Baseline comparison of VAS and WOMAC scores between CTG and IRG.

Variable	CTG Pre-treatment M ± SD	IRG Pre-treatment M ± SD	*F*	Partial eta-squared	*p*-value
VAS	7.07 ± 1.74	6.24 ± 3.12	0.692	0.612	0.409
WOMAC					
Pain	18.77 ± 2.78	20.17 ± 13.38	0.02	0.001	0.960
Stiffness	5.77 ± 1.00	5.13 ± 2.06	0.645	0.001	0.832
PF	56.10 ± 7.35	14.83 ± 16.22	0.086	0.001	0.770

Note: WOMAC: Western Ontario and McMaster Universities Osteoarthritis Index; M: mean; SD: standard deviation; "*" denotes the significance level, $p < 0.05$. The *p*-values are for parametric test and independent sample *t*-test for comparison groups.

Table 3. Post-treatment changes between CTG and IRG following 12 weeks of treatment.

Variable	CTG ($n = 30$) M ± SD	IRG ($n = 30$) M ± SD	*F*	Partial eta-squared	*p*-value
VAS	2.23 ± 4.34	6.24 ± 3.12	43.6	0.983	0.000*
WOMAC (%)					
Pain	16.97 ± 3.38	20.17 ± 13.38	246.08	0.809	0.000*
Stiffness	7.13 ± 2.06	10.33 ± 0.80	7.66	0.116	0.008*
PF	45.79 ± 9.08	14.83 ± 16.22	266.99	0.973	0.000*

Note: WOMAC: Western Ontario and McMaster Universities Osteoarthritis Index; M: mean; SD: standard deviation; "*" denotes the significance level, $p < 0.012$.

The *p*-value for each dependent variable for the quality of life is shown in Table 4.

There was a statistically significant difference in quality of life between the two groups after 12 weeks of intervention: $F = 2.96$; $p = 0.005$; Wilk's lambda = 0.623; and partial eta-squared = 0.37. When the results for the dependent variables were considered separately, the only difference to reach

Table 4. Baseline comparison of participants' quality of life between CTG and IRG.

Variable	CTG Pre-treatment M ± SD	IRG Pre-treatment M ± SD	*F*	Partial eta-squared	*p*-value
PF	54.57 ± 4.76	52.70 ± 4.88	2.160	0.036	0.147
RLPH	52.38 ± 5.62	52.42 ± 7.35	2.625	0.016	6.808
RLEP	67.09 ± 10.11	66.76 ± 5.57	0.463	0.080	0.499
E/F	60.98 ± 7.64	62.64 ± 6.70	1.510	0.508	0.414
EWB	65.67 ± 10.93	65.55 ± 6.52	0.463	0.025	0.223
SF	57.65 ± 8.57	57.95 ± 5.71	1.646	0.023	0.205
Pain	51.54 ± 7.67	50.92 ± 5.49	1.369	0.023	0.247
GH	50.82 ± 6.94	51.57 ± 4.17	0.652	0.011	0.423
PCS	52.37 ± 1.66	51.62 ± 2.56	4.210	0.054	0.540
MCS	63.10 ± 2.42	63.29 ± 1.62	1.095	0.019	0.300

Notes: PCS: Physical component summary; MCS: mental component summary; PF: physical function; RLPH: role of limitation due to physical health; RLEP: role of limitation due to emotional problems; E/F: energy/fatigue; EWB: emotional well-being; SF: social functioning; GH: general health; M: mean; SD: standard deviation; and "*" denotes the significance level, $p < 0.05$. "*" indicates the statistical significance.

Table 5. Post-treatment changes in QoL between the two groups (CTG and IRG).

Variable	CTG M ± SD	IRG M ± SD	*F*	Partial eta-squared	*p*-value
PF	80.07 ± 07	75.52 ± 52	0.56	0.010	0.456
RLPH	79.82 ± 7.87	74.05 ± 8.13	1.08	0.018	0.302
RLEP	83.70 ± 12.66	78.60 ± 5.99	0.01	0.000	0.920
E/F	65.14 ± 16.37	63.93 ± 9.05	0.05	0.001	0.001
WB	78.37 ± 11.68	71.63 ± 11.46	0.03	0.001	0.850
SF	75.24 ± 10.40	68.18 ± 10.25	1.02	0.017	0.316
Pain	72.42 ± 8.88	67.33 ± 6.49	3.97	0.064	0.051
GH	80.13 ± 11.69	52.70 ± 11.69	14.6	0.202	0.000*
PCS	78.27 ± 4.93	65.49 ± 3.49	7.84	0.119	0.007
MCS	72.90 ± 14.08	68.96 ± 5.60	1.64	0.028	0.205

Notes: PCS: Physical component summary; MCS: mental component summary; PF: physical function; RLPH: role of limitation due to physical health; RLEP: role of limitation due to emotional problems; E/F: energy/fatigue; EWB: emotional well-being; SF: social functioning; GH: general health; M: mean; SD: standard deviation; "*" denotes the significance level, $p < 0.005$.

statistical significance, using a Bonferroni-adjusted alpha level of 0.005, was general health (GH): $F = 14.64$, $p = 0.000$, and partial eta-squared = 0.20. An inspection of mean scores indicated combination therapy group reported higher levels of quality of life as shown in Table 5.

Discussion

This was a randomized controlled trial, aimed at evaluating the efficacy of CTG when compared with ILG in terms of pain severity, functional activities, and HRQoL, in patients with knee osteoarthritis. The limitation of this study is that the long-term effects of combination therapy and infrared radiation cannot be obtained because the study only assesses the 12-week effects, therefore the results of this study should be interpreted with caution. The general applicability is limited as it can only be applied to the population of patients with knee osteoarthritis. Other limitation of the study includes the inability to blind the research assistant who delivered the intervention because in standard RCT both the participants and those who delivered the interventions are blinded but in physiotherapy it may sound so difficult. Self-reported outcomes such as VAS, WOMAC, and SF-36 scales are also a limitation as they may be influenced by placebo effects and outcome expectation. Moreover, some participants might have been taking other analgesics which might be a limitation to the intervention; this aspect is beyond the control of the researchers.

According to the study findings, patients with knee OA treated with CTG had better improvement in pain, physical function, and particularly the GH component of HRQoL compared with patients in the IRG, over a period of 12 weeks. This study clearly indicated that combination therapy is an electrotherapeutic modality that reduces pain and improves functional activities and HRQoL of elderly people with knee osteoarthritis.

In patients with OA, pain is the primary, most important, and frequent clinical symptom that leads to limited functional activities and poor quality of life.[33,34] The primary goal of OA management is to alleviate the pain as well as improve functional activities and the quality of life of the individuals.[35]

In the current study, significant pain improvement reported by the CTG might be attributed to the combined effects of the electro-analgesia of IFC[11] therapy and thermal analgesic effects of continuous US therapy.[36] Several studies have shown that CT is an effective modality in the management of musculoskeletal disorders.[37,38]

Our findings were also supported by a study conducted by Švarcova *et al.*,[39] who studied the combined effects of therapeutic ultrasound, galvanic current, and shortwave diathermy in patients with knee osteoarthritis. They reported significant improvement in pain level.

In spite of the fact that the mechanisms by which CT relieves pain are not properly understood, studies have shown that IFC therapy achieves its electro-analgesic effects through the activation of large diameter nerve fibres to inhibit the nociceptive impulses from the small-diameter fibres at the posterior horn of the spinal cord to modulate pain.[11,40] OA pain is believed to be originating from both nociceptive and neuropathic pains as well as from unusual excitability in the nociceptive pathways of both peripheral nervous system and central nervous system (CNS).[41] The pain is proven to be associated with central sensitization as a result of continued nociceptive activities from the affected knee that leads to prolonged hyper-excitability of pain in the CNS.[42,43] IFC therapy may limit this prolonged abnormal hyper-excitation associated with pain observed in patients with knee OA. IFC therapy also achieves its electro-analgesic effects by blocking nociceptive impulses as explained by Melzack and Wall.[44]

Studies have shown that the application of continuous US therapy produces thermal effects.[45,46] Thermal therapies are physiologically known to increase tissue metabolism, collagen elasticity, capillary blood flow, and reduce muscle spasm.[47,48]

Yeğin *et al.*[36] reported that the US therapy is an effective treatment modality that reduces pain and improves physical function in the short term. In another study, Zeng *et al.*[49] reported that the continuous US therapy could be used for effective pain relief in the management of knee osteoarthritis. Studies have shown that US therapy is an effective modality in reducing pain and improving functional activities and quality of life in the management of patients with knee OA.[50,51]

Unlike our study and the above-reported findings, Welch *et al.*[52] conducted a systematic review aimed at studying the effectiveness of US therapy for[45] patients with knee OA. They reported US therapy to have no beneficial effects when compared with placebo and shortwave diathermy on pain and function in the management of patients with osteoarthritis. In addition, some controlled clinical studies have reported that US therapy had no benefits in improving pain and functional activities in the management of patients with knee osteoarthritis.[45,53]

There is no literature that reports CT is unsafe. In all the available clinical studies on the use of CT on musculoskeletal disorders, no single study reported the side effects, either in CTG or in ILG.[37,38,54] Likewise, in this current study no side effects had occurred during or after the CT treatment. Thus, the use of combination therapy was not associated with any negative or adverse effects in the management of knee OA.

The present study shows good improvement in pain relief, functional activities, and quality of life, but specifically the GH component of SF-36 quality of life showed improvement in patients treated with US and IFC therapies concurrently. The findings of this study add to the clinical evidence with regard to the use of CT in patients with knee OA.

Conclusion

Combination therapy was found to be an effective electrotherapeutic modality that can be used to relieve pain as well as improve functional activities and HRQoL in patients with knee osteoarthritis.

Conflict of Interest

The authors declare no competing interests.

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Author Contributions

Zubair Usman and Sonill Sooknunan Maharaj contributed to the study concept and design. Zubair Usman and Bashir Kaka helped in data acquisition and prepared the first draft of the paper. Sonill Sooknunan Maharaj revised the manuscript. All authors read and approved the final manuscripts.

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Relationships between lower extremity strength and the multi-directional reach test in children aged 7 to 12 years

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Objective: This study investigates the relationships between the Multi-Directional Reach Test (MDRT) and lower extremity strength in typical children.
Methods: The MDRT including forward, backward, leftward, and rightward directions was measured in 60 children aged between 7 and 12 years old with typical development. The lower extremity muscle groups were measured using a hand-held dynamometer.
Results: The reaching score in each direction had positive relationships with the strengths of several lower extremity muscle groups ($r = 0.26$ to $0.52, p < 0.05$). Only the strengths of the hip flexor and knee flexor muscles significantly correlated with the MDRT scores in all directions ($r = 0.26$ to $0.50, p < 0.05$).
Conclusion: This study highlights the strength of the hip and knee flexor muscle groups as being important domain to control balance in all directions. These findings may be used for therapists in planning a balance program to improve the limits of stability.

Keywords: Multi-Directional Reach Test; lower extremity strength; typical children; limits of stability.

Introduction

Balance is a fundamental skill for all movements in humans, such as activities involving standing, reaching, walking, running, or jumping.[1] Balance is defined as the ability to control the body's center of gravity relative to the base of support or limits of stability either at standing or during movement, which is achieved through the integrated action of musculoskeletal and neurological systems.[2,3] The development of the ability to balance in children is

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represented as a stage-like progression. The growth and maturation of the body systems in human follow a general developmental timeline.[4] Therefore, the development of the ability to balance in children is represented as a stage-like progress, which occurs through the development of specific systems involved in balance control abilities such as visual, vestibular, somatosensory, and musculoskeletal systems.[5–7] One factor that has direct influence on the ability to control balance, and also improvements in children, is muscle strength.[8,9] Several studies found that muscle strength, especially lower extremity muscle strength, is highly correlated with postural control or balance in the standing position.[3,9,10] The weakness of lower extremity muscles is a common factor associated with balance impairment that is a risk factor for postural instability and falling.[9,11–13]

Problems in postural control may cause reduced mobility in children and also restrict participation in the community.[14] By the age of 7–12 years, as middle childhood, the balance control in this age is still emerging as adult-like balance patterns but the balance is not yet fully completed.[15–17] Children are more prone to falls because of the variability in their movements with several immature body systems such as the musculoskeletal systems and neuromuscular system.[7] Postural impairment leading to falls in children may result in functional limitations, loss of confidence, and low self-esteem.[18] The fear of falling can also have adverse effects on the psychological and social development of the child.[19,20] Approximately 43% of child injuries in Asia in those aged 0–18 years were caused by falls.[19] Therefore, balance examination helps to investigate balance status and provides intervention to children with the risk of falling. The Multi-Directional Reach Test (MDRT) is one performance-based test in clinical balance assessment that measures the maximal reach distance in four directions including the forward, backward, leftward, and rightward directions during standing with the feet stationary.[20,21] Greater reach distance represents larger limits of stability, which indicates better balance ability.[20,21] The test can be easily completed by children requiring simple equipment. MDRT also yields results which can be interpreted quickly. It has also been shown to be reliable (ICC = 0.93 to 0.95) and valid (concurrent validity of MDRT with Berg Balance Scale; $r = 0.36$ to 0.48 and Timed Up and Go test; $r = 0.26$ to 0.44) for measuring dynamic standing balance.[21] Although most studies involving the MDRT were commonly used to assess balance in the elderly,[21–23] some studies had reported the functional reach and lateral reach tests in children.[1,14,24] A recent study investigated the normative reference scores using the MDRT in children.[20] Additionally, previous studies have reported correlations between muscle strength and clinical balance testing (e.g., Functional Reach Test, Berg Balance Scale, and Timed Up and Go test) in adults and the elderly.[25–27] Researchers found that reduced muscle strength may lead to a fall during dynamic tasks including reaching movements.[25,26,28] Although previous studies reported the effects of muscle strength on the functional reach test,[29,30] no study has documented the contributions of lower extremity strength in the MDRT. This finding attempts to investigate the relationship between lower extremity strength and the MDRT in children to provide the preliminary data for promoting health or rehabilitation.

The aim of this study was to examine the relationship between lower extremity strength and the MDRT for reaching distances. The strength of muscle groups might influence balance in different directions. This would enhance clinicians in planning rehabilitation program for improving the ability to control balance in specific directions.

Materials and Methods

Sixty participants, aged between 7 and 12 years (30 boys, 30 girls), were recruited from two schools in the Bangkok metropolitan region. These children were recruited using the convenience sampling technique with equal numbers of boys and girls for each age (boys = 5, girls = 5; $n = 10$). Children participated in this study were able to understand and follow commands. Exclusion criteria included children who (1) had any medical problems affecting their ability to stand or complete the tasks, (2) had musculoskeletal, balance, or visual problems that might affect balance and strength, and (3) had history of injuries or surgeries on the lower extremities. The information sheet, medical questionnaire, and consent form were given to the parents. All parents and children signed the informed consent forms which were approved by the University Ethics Review Committee for Research Involving Human Research Subjects.

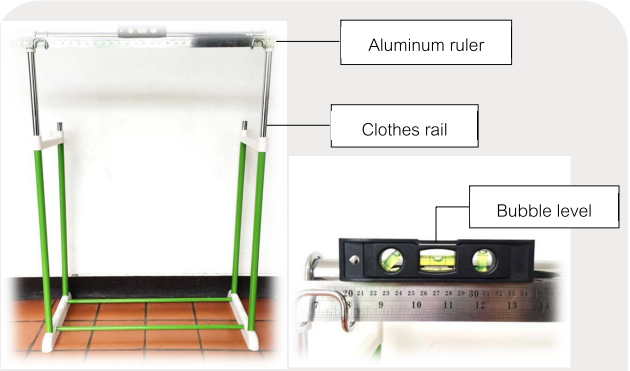

Fig. 1. MDRT tool including a meter stick made of aluminum and a bubble level.

After consent was given to participate in the study, anthropometric data including height and weight were collected for each child. Then, the MDRT was assessed in four directions randomly determined by computer. The MDRT tool included a meter stick made of aluminum and a bubble level used to ensure the meter stick was placed horizontally upon the floor (Fig. 1). Before measuring the MDRT, each child was instructed to stand barefoot on a piece of paper fixed to the floor and to take up a stance approximately a shoulder-width apart. The feet position was traced onto the paper to ensure the same starting point for all tests. The meter stick was set to the height of each child's acromion process. Test procedures were explained and demonstrated by the same tester. Then, the children were instructed to raise an outstretched arm to shoulder level and "reach as far (direction given) as possible without losing balance and without touching the ruler. For the backward direction, the children were instructed to "lean backward as far as possible". The difference in the distances between the middle fingertip at starting and ending positions was used as the reaching score. An average of three successful trials in each direction was used for the analysis. A fourth trial was only conducted for subjects if they lost their balance or took a step during the testing in one of the trials. If did so twice, they were excluded from the study. The MDRT in this study was the high inter-rater reliability (ICC = 0.80 – 0.86) and intra-rater reliability (ICC = 0.89 – 0.97) in all directions. For the inter-rater reliability, 10 children who were 7–12 years old were recorded by two raters who are physical therapists. The first rater recorded three trials in each direction, considering the average of the three times for the calculation. The second rater recorded the same measurement. The subjects took a rest of 5 min between the raters. For the intra-rater reliability, the same children were re-tested the following week. All of the procedures which were previously explained were repeated during the re-test. However, the MDRT was performed before the measurement of lower extremity strength to avoid any fatigue that may occur.

Lower extremity strength was measured using a hand-held dynamometer (HHD; model 01165 Lafayette Manual Muscle Test System, Lafayette Instrument Company, Lafayette, USA) that was set to read force in Newtons (N). Muscle strength was tested by using the isometric break test in eight muscle groups, comprising (a) hip flexor, (b) hip extensor, (c) hip adductor, (d) hip abductor, (e) knee flexor, (f) knee extensor, (g) ankle dorsiflexor, and (h) ankle plantar flexor. The testing procedure followed Ibrahim *et al.*[9] and Eak *et al.*[31] as shown in Table 1. Standardized instruction was given to all children to "try to hold the testing position and do not let me push or pull your leg" by the other tester (the 2nd tester) to blind between testers. Inter-rater and intra-rater reliabilities using the HHD in this study were of high reliability (ICC = 0.83 – 0.89, ICC = 0.93 – 0.99), respectively. For the inter-rater reliability, 10 children who were 7–12 years old were measured by two raters who are physical therapists. The first rater recorded three trials in each muscle group, considering the maximum force of three times for analysis, and resting 1 min between trials. The second rater recorded the same measurement. The subjects were given a rest of 5 min between raters. For the intra-rater reliability, the same children were re-tested the following week. All of the procedures which were previously explained were repeated during the re-test.

All children received an explanation of the procedures and practiced once with submaximal force to ensure correct performance. Participants were tested for three trials in each muscle group, and rested 1 min between trials to avoid possible fatigue.

Statistical Analysis

Statistical analysis was performed with IBM SPSS Statistics (version 22.0) for Windows. Normality of data distribution was defined by the Kolmogorov–Smirnov test. Descriptive statistics were obtained

Table 1. Procedure of lower extremity strength testing.

No.	Muscle group	Testing position	Child stabilization	Dynamometer placement
(1)	Hip flexor	Supine, hip and knee flexed 90°	Trunk	Mid-point on the anterior side of the distal femur (10 cm above the base of patella)
(2)	Hip extensor	Supine, hip, and knee flexed 90°	Trunk	Mid-point on the posterior side of the distal femur (same level as HF)
(3)	Hip adductor	Supine, hip, and knee extended	Trunk and the other leg	Medial side of the distal femur (same level as HF)
(4)	Hip abductor	Supine, hip, and knee extended	Trunk and the other leg	Lateral side of the distal femur (same level as HF)
(5)	Knee flexor	Sitting, hip, and knee flexed 90°	Thigh	Posterior side of the distal tibia (10 cm above the lateral malleolus)
(6)	Knee extensor	Sitting, hip, and knee flexed 90°	Thigh	Anterior side of the distal tibia (same level of KF)
(7)	Ankle dorsiflexor	Supine, hip, knee extended and ankle in neutral position	Lower limb proximal to ankle	Dorsum of foot proximal to the metatarsophalangeal joint
(8)	Ankle plantar flexor	Supine, hip, knee extended and ankle in neutral position	Lower limb proximal to ankle	Sole of foot proximal to the metatarsophalangeal joint

for the values of the MDRT and lower extremity strength. Pearson product-moment correlation coefficient was used to examine the relationships between lower extremity strength and the MDRT in each direction. The strength of correlation in this study was considered as follows: good to excellent correlation (> 0.75), moderate to good correlation (0.51 to 0.75), fair correlation (0.25 to 0.50), and little to no correlation (< 0.25).[32] Statistical significance was considered at $p < 0.05$.

Results

The characteristics of participants for each age group are shown in Table 2. Table 3 shows the mean MDRT scores in each direction and lower extremity strength values among the children aged 7–12 years. The data on muscle strength were obtained from the average of both limbs. The relationships between lower extremity strength and the MDRT in each direction, as shown in Table 4, showed that the reaching score in each direction correlated with several muscle groups. In the forward direction, the results of Pearson's correlation revealed a fair correlation between the forward reaching score and the strength of the hip flexor, hip extensor, knee flexor, knee extensor, and ankle plantar flexor muscle groups ($r = 0.27$ to 0.31, all $p < 0.05$). In the backward direction, fair correlation was found between the backward reaching score and the strength of all lower extremity muscle groups ($r = 0.30$ to 0.50, $p < 0.05$); in particular, the hip abductor revealed moderate correlation with the backward reaching score ($r = 0.52$, $p < 0.001$). Additionally, fair correlation was observed between the leftward reach distance and the strength of the hip flexor, hip extensor, hip abductor, knee flexor, and knee extensor muscle groups ($r = 0.29$ to 0.36, p-value < 0.05). Also, the rightward reach distance showed a fair correlation

Table 2. Characteristics of the participants.

Age (year)	7 ($n = 10$) (mean ± SD)	8 ($n = 10$) (mean ± SD)	9 ($n = 10$) (mean ± SD)	10 ($n = 10$) (mean ± SD)	11 ($n = 10$) (mean ± SD)	12 ($n = 10$) (mean ± SD)
Height	122.0 ± 3.5	127.7 ± 2.5	134.6 ± 5.4	137.2 ± 3.4	142.9 ± 4.3	147.9 ± 5.8
Weight	24.5 ± 3.2	25.3 ± 2.6	29.3 ± 3.5	34.1 ± 4.7	36.7 ± 4.8	39.3 ± 4.5

Table 3. Results of the MDRT (cm) and lower extremity strength (N) values.

Age (year)	7 ($n = 10$) (mean ± SD)	8 ($n = 10$) (mean ± SD)	9 ($n = 10$) (mean ± SD)	10 ($n = 10$) (mean ± SD)	11 ($n = 10$) (mean ± SD)	12 ($n = 10$) (mean ± SD)	Mean (mean ± SD)
Forward (cm)	11.3 ± 2.6	10.5 ± 3.2	11.1 ± 2.3	11.8 ± 1.4	12.1 ± 2.3	11.9 ± 2.5	11.4 ± 2.4
Backward (cm)	6.8 ± 2.0	6.2 ± 1.4	6.9 ± 1.3	9.1 ± 2.5	8.7 ± 1.7	10.1 ± 2.6	7.8 ± 2.3
Leftward (cm)	9.3 ± 0.9	9.9 ± 2.2	9.4 ± 1.8	9.9 ± 1.3	10.3 ± 2.1	9.9 ± 1.5	9.6 ± 1.9
Rightward (cm)	9.1 ± 1.2	9.1 ± 2.5	9.1 ± 1.8	10.1 ± 1.7	9.6 ± 0.8	10.7 ± 2.6	9.6 ± 1.7
Hip flexors (N)	120.2 ± 14.6	121.1 ± 18.8	135.3 ± 23.8	144.7 ± 17.8	174.6 ± 25.5	178.5 ± 29.5	145.7 ± 31.7
Hip extensors (N)	274.1 ± 50.7	224.1 ± 53.8	258.7 ± 76.3	290.6 ± 30.1	315.8 ± 74.9	332.3 ± 69.9	282.6 ± 69.0
Hip adductors (N)	94.4 ± 20.3	105.7 ± 22.4	130.1 ± 27.5	131.1 ± 18.6	155.6 ± 43.1	159.3 ± 47.2	129.4 ± 38.7
Hip abductors (N)	124.1 ± 17.3	118.9 ± 21.5	144.7 ± 32.8	150.4 ± 22.7	182.6 ± 36.8	194.7 ± 48.5	152.6 ± 41.4
Knee flexors (N)	100.1 ± 14.3	112.7 ± 14.0	130.1 ± 25.1	141.4 ± 17.5	157.9 ± 34.0	163.1 ± 36.2	134.2 ± 33.2
Knee extensors (N)	149.8 ± 20.7	139.7 ± 29.0	173.1 ± 52.7	207.1 ± 41.1	212.7 ± 51.5	234.9 ± 45.7	186.2 ± 53.0
Ankle dorsiflexors (N)	145.6 ± 19.4	139.6 ± 23.8	164.9 ± 27.4	189.5 ± 21.9	212.2 ± 40.8	213.1 ± 40.3	177.5 ± 41.5
Ankle plantarflexors (N)	411.1 ± 61.3	354.2 ± 87.1	417.9 ± 115.7	453.6 ± 70.3	439.1 ± 84.2	515.4 ± 41.6	440.9 ± 93.9

Table 4. Relationships between lower extremity strength and the MDRT in each direction.

	MDRT			
Variables	Forward	Backward	Leftward	Rightward
Hip flexors	0.28*	0.48**	0.33*	0.28*
Hip extensors	0.28*	0.42**	0.36**	0.24
Hip adductors	0.15	0.43**	0.20	0.09
Hip abductors	0.21	0.52**	0.30**	0.21
Knee flexors	0.27*	0.50**	0.29*	0.26*
Knee extensors	0.27*	0.48**	0.32*	0.25
Ankle dorsiflexors	0.20	0.44**	0.21	0.27*
Ankle plantar flexors	0.31*	0.30*	0.26	0.32*

Notes: *statistically significant, $p < 0.05$, **statistically significant, $p < 0.001$.

with the strength of the hip flexor, knee flexor, ankle dorsiflexor, and ankle plantar flexor muscle groups ($r = 0.26$ to 0.32, $p < 0.05$).

Discussion

This is the first study to investigate the relationship between lower extremity strength and the MDRT score in children. The results of Pearson's correlation showed that the lower extremity strength in several muscle groups fairly correlated with the MDRT scores.

In the forward direction, the reaching score correlated best with the strength of the ankle plantar flexor muscle group. The eccentric plantar flexion of the ankle controls the anterior lean distance without falling. This relationship can be explained by the mechanical demands of preventing the falling forward of the trunk during the forward reaching task.[10,28,33,34] This finding is consistent with the results of Daubney and Culham,[10] who identified the strength of the ankle plantar flexor muscle as contributing to the prediction of the forward reaching score. The other possible explanation would involve the direction specific muscles in the caudal–cranial direction. In standing position, the muscles change into a distal-to-proximal recruitment order caused by the body parts near the support surface being in the need of stabilization.[35]

Additionally, the results of this study indicated significant correlation between the strength of the hip and knee muscle groups in the sagittal plane and the distance of the forward reach test. It is possible that the agonistic and antagonistic muscles of the hip and knee took the pattern of coactivation which assisted the stabilization of postural control. The activity of the hip extensor group assists the knee extensor muscles to control the knee positions and to prevent excessive trunk flexion.[36] The strength of the hip flexor muscle group is important for the balance and functional performance that is used to restore equilibrium to change the postural control.[37] According to the previous studies, researchers suggested that the knee extensor muscle group comprises the antigravity muscles necessary to perform balance control and functional activities in standing.

The decrease in knee extensor strength is the one factor influencing falls.[38–40] Also, the strength of the knee flexor group acts mainly to prevent hyperextension of the knee during forward reaching.[33] The activity patterns of knee flexor muscles including the semimembranosus, semitendinosus, and biceps femoris while performing the reach test may act mainly as a breaking function in the forward direction.[41] This finding demonstrated that the agonist–antagonist muscles might activate coordinately the surrounding knee joint. However, both proximal and distal muscles are recruited equally in younger ages, but with increasing age, distal muscles become more activated.[33,42]

The strength of the hip and knee flexor muscles is not only significantly correlated with forward reaching score but also in lateral reaching scores. One possible explanation may be that the hip flexor muscle group including the two major portions of iliacus and psoas originates from the iliacus bone and lumbar spine, respectively, and inserts on the trochanter of the femur. In a standing position, the specific function of the iliacus muscle is important to stabilize between the pelvis and hip joints. The psoas muscle assists in stabilizing the lumbar spine in the frontal plane.[43] This means that the iliopsoas muscle may act mainly as a stabilizer muscle when performing the reaching task in the lateral direction. Also, hip abductor muscles are crucial to minimize pelvic rotation and maintain balance in the frontal plane.[36]

However, the left and right reaching tasks demonstrated correlations with different muscle groups. One possible explanation may be the familiarity with the dominant reaching of the activity in daily life. All participants in this study preferred the use of right hand for reaching. Possibly, rightward reaching makes it easier to control the center of mass (COM) within the base of support. The strength of the distal muscles following dorsiflexor and plantar flexor muscles would provide adequate stabilization during reaching. Conversely, leftward reaching must exert hip and knee extension strength to help maintain reaching balance in this task. Knee extensor strength correlated with dynamic postural stability and influence on functional task performance.[44] However, in order to clarify the mechanism of these strategies, the kinetic parameter and muscle activity in each lower extremity should be further studied.

In the backward direction, it is interesting that there was a significant correlation between the backward reaching score and the strength of all lower extremity muscle groups. The results revealed that the magnitude of correlations was quite similar. This implies that the reaching performance in the backward direction needs to coordinate the strength of all muscle groups for achieving the reaching task. The reasons for these correlations may result from the backward reaching being a more difficult task that is unfamiliar and that has no visual acuity.[20,23] Most daily activities that have better balance control are performed in front of the body.[20] The difficulty of the balance task relates to the recruitment of the antagonistic muscles and the modulation of the degree of contraction.[41] Antagonistic coactivation is a phenomenon in the development of postural adjustments.[7] Muscle co-contraction increases when balance is more challenged[45] and decreases when the task is easier.[46] Therefore, leaning backwards may require a lot of effort to control the body without falling. This could be the reason for the relatively low reach scores in the backward direction. In addition, from a biomechanical perspective, the hip extension angle is much smaller than the hip flexion angle. It may result in the backward reaching score lesser than forward reaching score.

Accordingly, this study demonstrates that hip and knee flexor strength significantly correlated with reach scores in all directions. Therefore, therapist should pay attention to the strength of the hip and knee flexor muscle groups in children to improve the limits of stability through balance training in all directions. However, results of this study show that the MDRT was weakly correlated with lower extremity strength. One possible explanation would involve the position of testing. The MDRT was performed during standing but the muscle strengths were tested in supine or sitting position. Nevertheless, in this study, we only examined the muscle strength of the lower extremities. Trunk muscles might affect the reaching task in the four directions. A further study could investigate the strength of the trunk muscles and muscle recruitment differences of MDRT in children with movement disorders.

Conclusion

The results of our study demonstrated that the strength of the lower extremity muscle groups is

correlated with the MDRT in each direction. This study indicated that the strength of the hip and knee flexor muscle groups was implicated in increased reaching in four directions. This may be helpful for therapists in planning rehabilitation programs to improve the limits of stability.

Conflict of Interest

The authors have no conflict of interest relevant to this paper.

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Author Contributions

Collecting data, analysis of data, and manuscript writing were carried out by Hirunyapinun. Analysis of data, critical discussion, revising manuscript, and management of the study were carried out by Taweetanalarp. Tantisuwat contributed to critical discussion and revising manuscript.

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