Original Article

PTRS Physical Therapy Rehabilitation Science

http://dx.doi.org/10.14474/ptrs.2014.3.1.27
pISSN 2287-7576
eISSN 2287-7584

Phys Ther Rehabil Sci
2014, 3 (1), 27-32
www.jptrs.org

Wheelchair martial arts practitioners have similar bone strength, sitting balance and self-esteem to healthy individuals

Shirley S. M. Fong[a], Shamay S. M. Ng[b], Anthony O. T. Li[c], X. Guo[b]

[a]Institute of Human Performance, University of Hong Kong, Hong Kong, China
[b]Department of Rehabilitation Sciences, Hong Kong Polytechnic University, Hong Kong, China
[c]Hong Kong PHAB Martial Art Association, Hong Kong, China

Objective: The aim of this study was to compare the radial bone strength, sitting balance ability and global self-esteem of wheelchair martial arts practitioners and healthy control participants.
Design: Cross-sectional study.
Methods: Nine wheelchair martial art practitioners with physical disabilities and 28 able-bodied healthy individuals participated in the study. The bone strength of the distal radius was assessed using the Sunlight Mini-Omni Ultrasound Bone Sonometer; sitting balance was quantified using the modified functional reach test (with reference to a scale marked on the wall); and the self-administered Rosenberg self-esteem (RSE) scale was used to measure the global self-esteem of the participants. The velocity of the ultrasound wave (speed of sound, m/s) traveling through the outer surface of the radial bone was measured and was then converted into a T-score and a Z-score. These ultrasound T-score and Z-score that represent bone strength; the maximum forward reaching distance in sitting (cm) that represents sitting balance; and the RSE total self-esteem score that indicates global self-esteem were used for analysis.
Results: The results revealed that there were no statistically significant between-group differences for radial bone-strength, maximum forward reaching distance, or self-esteem outcomes.
Conclusions: The wheelchair martial arts practitioners had similar radial bone strength, sitting balance performance and self-esteem to able-bodied healthy persons. Our results imply that wheelchair martial arts might improve bone strength, postural control and self-esteem in adult wheelchair users. This new sport－wheelchair martial arts－might be an exercise option for people with physical disabilities.

Key Words: Health, Martial arts, Self concept, Sports for persons with disabilities

Introduction

Wheelchair users are prone to developing osteoporosis because their sedentary lifestyle may increase bone reabsorption and cause a reduction in bone mineral density (BMD) [1,2]. Osteoporosis is a significant issue for physically disabled people, as it increases the risk of fractures, which may in turn increase morbidity and mortality in people already disabled by chronic disorders [3]. It is well known that regular physical activity can increase bone mass and maintain BMD in able-bodied people [4]. However, there is little evidence to support the beneficial effects of physical activity among wheelchair-dependent people. To the best of our knowledge, only one study has compared the BMD of wheelchair athletes and physically able athletes. The results revealed that the BMD of the arms of wheelchair athletes was higher than that of the healthy individuals [2]. However, the study included a wide range of wheelchair sports, including basketball, track and field and tennis. A more homogenous group is necessary to explore the effect of

Received: 13 March, 2014 **Revised:** 14 May, 2014 **Accepted:** 27 May, 2014

Corresponding author: Shirley S. M. Fong

Institute of Human Performance, University of Hong Kong, Pokfulam, Hong Kong, China
Tel: 852-2831-5260 **Fax:** 852-2855-1712 **E-mail:** smfong@hku.hk

a particular wheelchair sport on the bone strength of people with physical disabilities.

Sitting balance is also a concern among long-term wheelchair users because these individuals perform daily activities from a sitting position, thus good sitting balance control could improve their quality of life [5]. A previous study showed that a video game-based exercise approach may improve dynamic sitting balance control in wheelchair-dependent persons, specifically people with chronic spinal cord injury [6]. However, another study showed that training in a dynamic sport (kayaking) did not improve sitting balance in paraplegics [5]. These conflicting findings are mainly due to the different types and durations of training (6 months of video game playing versus 8 weeks of kayaking) between the two studies. Exploring a specific physical activity with a standardized training protocol is thus necessary to explore sitting balance control among long-term wheelchair users.

Empirical studies that have examined the self-esteem of people with physical disabilities generally suggest that people with disabilities have a poorer self-concept [7] and self-esteem [8] than non-disabled individuals. Self-esteem is reported to be related to aggression, antisocial behavior, and delinquency [9]. Training in the martial art of taekwondo has been shown to improve self-esteem [10] and reduce delinquent tendencies in healthy young people [11]. These findings, overall, suggest that martial arts training may have psychological benefits for wheelchair users. However, directly measuring the psychological attributes (e.g., self-esteem) of wheelchair-dependent people who have received martial arts training is necessary to confirm this postulation.

Wheelchair martial arts is a new sport developed by Master Anthony O. T. Li and his team in 2004. It was modified from the traditional Korean martial art of taekwondo to cater for the needs of people in wheelchairs. Participants can practice martial arts skills such as punching, blocking and striking in a seated posture. The training regime is progressive and standardized [12]. We hypothesize that training in wheelchair martial arts will (1) improve/preserve forearm bone strength due to its combative and impactful nature [4]; (2) improve sitting balance control because considerable trunk control is required during training [12]; and (3) improve self-esteem in people with physical disabilities who rely on a wheelchair to ambulate. Therefore, the objective of this cross-sectional and exploratory study was to compare the radial bone strength, sitting balance ability and global self-esteem of wheelchair martial arts practitioners and healthy control participants.

Methods

Subjects

Adult wheelchair users with physical disabilities (n=9) were recruited from the Hong Kong PHAB Martial Art Association, which provides wheelchair martial arts training for people with disabilities. The participants met the following inclusion criteria: (1) had physical disabilities (e.g., cerebral palsy); (2) depended on a manual or powered wheelchair for ambulation; (3) were aged between 16 and 60 years; (4) had normal cognitive, visual and hearing functions; and (5) had practiced wheelchair martial arts for at least three years. The exclusion criteria were that they (1) had weak trunk control (e.g., cannot sit upright) and required trunk stabilization devices in sitting; (2) had chronic medical problems (e.g., epilepsy) or psychiatric disorders that might affect their test performance; (3) had significant visual or vestibular problems that might affect their balance performance; or (4) had recent injuries or unstable medical conditions. The participants in the control group were recruited from the University of Hong Kong (n=28). They met the same inclusion and exclusion criteria except that they were physically able bodied, could ambulate independently without the use of walking aids and had received no martial arts training in the previous two years.

Procedures and measurements

Ethical approval was obtained from the University of Hong Kong and written informed consent was obtained from each participant before data collection. The data were collected by two physiotherapists and trained student helpers following the Declaration of Helsinki guidelines. Relevant information such as general health and exercise habits were obtained by interviewing the participants. The physical activity level (metabolic equivalent [MET] hours per week of each participant was estimated based on the compendium of physical activities [13], which involved asking what type of physical activity they were most actively engaged in during a typical week and the exercise intensity (light, moderate, hard). Physical activity level was then calculated by the following equation: MET value of the activity x duration (hours) and frequency (times per week). After the interview, all participants underwent the following assessments in random order.

Figure 1. Radial bone strength assessment.

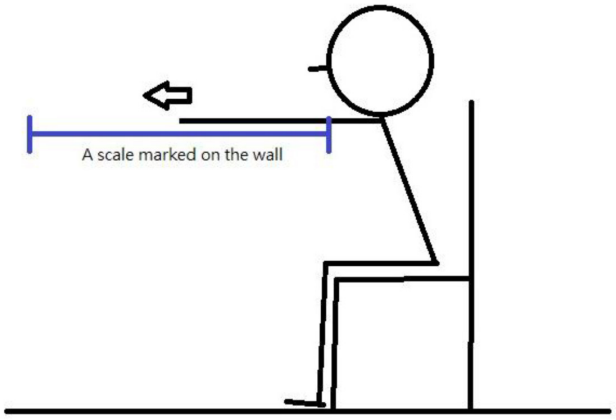

Figure 2. Sitting balance assessment.

Radial bone strength

The bone strength of the distal radius of the dominant arm was assessed using a Sunlight Mini-Omni Ultrasound Bone Sonometer (Sunlight; BeamMed Ltd., Petah Tikva, Israel). This technique provides a reliable and precise measurement of bone strength at the distal radius with an intra-operator precision of 0.36% and in-vivo precision of 0.4%-0.8% [14-16]. The detailed assessment procedures are reported in Fong *et al*. [17]. Briefly, the ultrasound transducers within the probe were rotated slowly around the distal radius by the tester (Figure 1). The velocity of the ultrasound wave (speed of sound [SOS], m/s) traveling through the radial bone (outer 2-6 mm) was measured. The SOS values were then converted into a T-score and a Z-score using the inbuilt computer software [18]. The T-score indicates the standard deviation relative to the population reference values of healthy young adults, while the Z-score represents the standard deviation from the mean of an age- and gender-matched population. These parameters reflect the bone's fragility and have been shown to be highly correlated with bone strength [18,19]. Both the SOS T-score and SOS Z-score were used for analysis.

Sitting balance

A modified functional reach test was used to assess the sitting balance of the participants, because it is a reliable measurement of sitting balance in non-standing people (intraclass correlation coefficient [$ICC_{3,2}$]=0.85-0.94) [20]. The participants were invited to sit in a wheelchair with the armrests removed or a chair without armrests. The supporting base was solid and the pelvis and lower limbs were not fixed. The maximal voluntary forward-reaching distance (anatomical landmark: third metacarpal) was measured twice using a scale marked on the wall [20] (Figure 2). The highest forward-reaching distance value, which represents the best sitting balance performance, was used for analysis.

Global self-esteem

The widely used Rosenberg self-esteem (RSE) scale was chosen to measure global self-esteem, defined as the overall feeling of satisfaction or dissatisfaction with oneself. It is a 10-item self-report questionnaire containing 5 positively worded items and 5 negatively worded items. The total self-esteem score (i.e., the sum of the positively worded items and the reverse-scored, negatively worded items) was used for analysis. Lower scores indicate higher self-esteem. This scale has a high reliability (r=0.85-0.88), good internal consistency (Cronbach's alpha=0.88) and good concurrent, predictive and construct validity [21,22].

Statistical analysis

The following statistical analyses were performed using the IBM SPSS Statistics 20.0 software (IBM Co., Armonk, NY, USA). Descriptive statistics (means and standard deviations) were used to describe all of the variables of interest. Independent t-tests were used to compare the continuous demographic variables (age, weight, height, body mass index [BMI] and physical activity level), while the chi-square (χ^2) test was used to compare the categorical demographic variable (sex) between the wheelchair martial arts group and the healthy control group. To compare the radial bone strength between the two groups while accounting for the confounding factors (i.e., those demographic variables that showed a significant between-group difference), a single

multivariate analysis of covariance (MANCOVA) incorporating both T-scores and Z-scores was performed. This statistical procedure was used to reduce the risk of type I errors associated with multiple comparisons. Independent t-tests were used to compare the sitting balance (maximum forward reaching distance) and self-esteem measures. Effect sizes (partial eta-squared for MANCOVA and Cohen's d for independent t-tests) are also presented for each outcome variable. Partial eta-squared values of 0.01, 0.06, and 0.14 represent small, medium and large effect sizes, respectively. Cohen's d values of 0.20, 0.50 and 0.80 are considered to be small, medium and large effect sizes, respectively [23]. The significance level was set at 0.05 (two-tailed) for all of the statistical analyses.

Results

Seven young people with life-time spastic cerebral palsy and two people with unknown causes of physical disability participated in the study. Independent t-tests revealed that body height and physical activity level differed between the two groups ($p < 0.05$; Table 1); therefore, these two demographic variables were treated as covariates in the subsequent MANCOVA. The results of the MANCOVA showed an overall non-significant difference in radial bone strength between the two groups. Thus, the between-group difference for each individual bone-strength outcome was also not significant. No difference was found between the two groups in the sitting balance outcome measure or the self-esteem outcome measure (Table 2).

Discussion

This novel study compared the bone strength, sitting balance performance and self-esteem of wheelchair martial arts practitioners and able-bodied controls. As expected, the results revealed that these physical and psychological parameters were comparable between the two groups despite the fact that the wheelchair martial arts group generally had lower physical activity levels than the healthy control group. Previous studies have found that long-term wheelchair users without martial arts experience had higher bone reabsorption and lower BMD than ambulatory individuals [1,2]. In this study, the long-term wheelchair users who re-

Table 1. Participant characteristics (N=37)

Characteristic	Wheelchair martial arts group (n=9)	Healthy control group (n=28)	t/χ^2	*p*
Age (y)	29.2 (12.3)	21.4 (2.3)	−1.913	0.091
Sex (male/female)	8/1	18/10	1.973	0.160
Weight (kg)	58.8 (16.2)	63.3 (11.5)	0.694	0.493
Height (cm)	151.7 (11.4)	169.7 (7.5)	4.237	<0.001
BMI (kgm^{-2})	23.8 (5.8)	21.8 (2.6)	−1.158	0.256
Physical activity level (metabolic equivalent hours per week)	13.3 (12.6)	36.0 (28.9)	2.268	0.030

Values are presented as n or mean (SD).

Table 2. Comparison of outcome measures (N=37)

Outcome measures	Wheelchair martial arts group (n=9)	Healthy control group (n=28)	F/t	*p*	Effect size
Radial bone strength (dominant side)					
SOS T-score	−1.8 (1.7)	−1.3 (1.0)	0.312	0.581	0.012
SOS Z-score	−1.1 (1.4)	−0.3 (1.0)	0.142	0.709	0.005
Sitting balance					
Maximum forward reaching distance (cm)	38.2 (15.6)	41.2 (12.1)	0.605	0.549	0.215
Global self-esteem					
RSE total self-esteem score	21.6 (4.4)	21.9 (4.5)	0.215	0.831	0.067

Values are presented as mean (SD).
SOS: speed of sound, RSE: Rosenberg Self-Esteem.
The effect sizes for radial bone strength were calculated in partial eta-squared values, and the effect sizes for sitting balance and self-esteem measure were calculated as Cohen's d values.

ceived regular martial arts training had comparable bone strength to healthy individuals. These findings collectively suggest that wheelchair martial arts training may improve or maintain bone strength in people with physical disabilities. The retention or improvement in radial bone strength associated with martial arts training could be explained by Wolff's law of bone remodeling, which proposes that the internal structure of bone adapts to mechanical demands, such that the orientation of the trabeculae coincides with the stress trajectories [24]. Martial arts training involves a number of high-impact striking techniques, hence bone may become stronger to resist the external load (force) imposed on it during training [17]. This may explain why the wheelchair martial arts practitioners had comparable bone strength to that of healthy young individuals.

This is the first study to show that wheelchair martial arts practitioners and able-bodied controls have similar sitting balance performance, as quantified by their forward reaching distance. This result suggests that martial arts training in a wheelchair may maintain or improve sitting balance control, particularly in the forward direction, among people with physical disabilities. This finding was anticipated, because reaching and striking in different directions are practiced repeatedly during wheelchair martial arts training (Figure 1). According to the motor learning principle, the amount of practice is positively associated with skill retention and transfer [25]. Therefore, our experienced wheelchair martial arts practitioners could have transferred their martial arts postural control skills to the modified functional reach test, and hence were able to demonstrate normal sitting balance performance.

Our results also show that wheelchair martial arts training may heighten self-esteem, specifically self-acceptance, among people with physical disabilities, who often have low self-esteem. This finding is in line with previous studies showing that short-term martial arts training is sufficient to improve young people's self-esteem [10], and that this improvement is positively correlated with rank [26]. All of our wheelchair martial arts practitioners were of middle or senior rank (green belt or above). Therefore, it is consistent that their self-esteem was comparable to that of healthy individuals.

Our study has a number of limitations. First, there may have been a self-selection bias due to convenience sampling. Second, we cannot infer the benefits of wheelchair martial arts training based on the current results because of the cross-sectional research design. Third, several confounding factors, such as body height which may affect reaching distance, the onset of wheelchair martial arts training and the type of physical impairment, were not taken into account. Further studies should use a randomized controlled study design, include a more homogeneous group of participants and taking the confounding factors into account.

To conclude, wheelchair martial arts practitioners had similar radial bone strength, sitting balance performance and self-esteem to able-bodied healthy persons. This new sport－wheelchair martial arts－may be an exercise option for people with physical disabilities.

Acknowledgements

The authors would like to thank Mr. S. W. Lau, Mr. Harry C. H. Leung and Mr. S. L. Wong for their assistance, and the University of Hong Kong BSc (Exercise and Health) students and all of the study participants.

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