

Physical performance measures following ten weeks of taekwondo training in children: A pilot study

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Abstract: The primary purpose was to examine changes in balance, lower extremity (LE) power and flexibility following 10 weeks of taekwondo (TKD) training and to determine if this was different in children classified as healthy weight (HW) and overweight (OW)/obese. Participants included 17 children (HW: n = 11, OW/obese: n = 6). Data were collected on balance, LE power and flexibility at baseline and 10 weeks. Balance was assessed with eyes open in normal (NSEO), tandem (TSEO), single (SLEO) stances and with eyes closed for normal (NSEC) and tandem (TSEC) stances. Center of pressure displacements in mediolateral (X_{avg}) and anteroposterior (Y_{avg}) directions; and average velocity (V_{avg}) were calculated. Analyses included two-way ANOVA and Mann Whitney U tests ($P < 0.05$). Balance data indicated significant interaction effects for X_{avg} in NSEO, Y_{avg} in TSEO; time effects for Y_{avg} in NSEO, NSEC and SLEO and V_{avg} in SLEO conditions. A significant group effect was shown for V_{avg} in the NSEO, NSEC and TSEO and for Y_{avg} in TSEC conditions. Flexibility decreased significantly with TKD. Findings suggest that 10 weeks of TKD training may improve balance in children, and OW/obese group may have greater improvements in balance with eyes open compared to their peers.

Key Words: childhood obesity, physical activity, martial arts



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1 Introduction

Overweight (OW) and obesity in children continues to be an epidemic throughout the United States (US). Nationally, the current prevalence for a child being classified as obese is reported as 17.7%, whereas the prevalence for a child being classified as either obese or overweight (OW) is 34.2% [1, 2]. Children who are currently obese and/or OW have an increased risk of developing short and long term health consequences [3]. Literature has shown obesity to be associated with an increased risk of pulmonary, orthopedic, neurological, gastroenterological, endocrine, cardiovascular, and inflammation disorders [4]. Numerous research studies suggest that the most appropriate intervention to overcome obesity is increasing physical activity and a healthy change in diet [3, 5].

Promoting physical activity in children is the primary focus to decrease the prevalence of children who are OW or obese [6]. Centers for Disease Control (CDC) guidelines suggest that children and

adolescents should participate in 60 minutes or more of moderate to vigorous aerobic activity per day, which should include vigorous-intensity exercise and bone as well as muscle strengthening activities on at least three days of the week [6, 7]. Current research suggests that less than half of the children in the US are meeting the current recommended physical activity guidelines [8]. Additionally, studies report that physical education classes are suboptimal and do not meet the physical activity requirements in children suggesting a role for sport specific training outside of schools [9, 10].

For decades, taekwondo (TKD) has been a popular form of exercise and self-defense performed by adults. TKD involves lower extremity positioning while simultaneously performing blocking, punching, chopping movements and promotes maintaining static and dynamic balance during activities [11, 12]. The vigorous activity completed during TKD may correspond with the CDC's recommendations in children to focus on aerobic, weight-bearing, muscle strengthening, and bone strengthening exercises during physical activity sessions. TKD is unique in focusing on lower extremity strength, power, and flexibility [13-16]. Studies report that adults who participate in TKD may experience an improvement in physiological measures such as balance, power, muscular strength, flexibility [11, 15, 17]. Less literature exists in children about benefits of TKD. In adolescents, TKD training, in addition to school based physical education classes, has shown to promote increased levels of physical activity for young children [18]. Studies in children, aged 11-14 years, indicate that children who participated in TKD training exhibited higher levels of performance of standing balance (static and dynamic) with an increase in development of postural control and vestibular function, as compared to age-matched, sedentary, healthy subjects [19]. Youth participation in TKD sessions has been related to increased explosive leg power, flexibility, and static balance [20].

Given the focus on improving lower extremity strength and balance with TKD, this activity may be applicable to children who are OW/obese. In children who are OW/obese studies have linked increased body mass index with decreased postural control and decreased lower extremity strength [21-24]. Participating in low frequency TKD for 50 minutes a day, twice per week for 12 weeks while also attending school based physical education classes, has been shown to reduce percentage of body fat and body mass in adolescent females with an improvement in measures of lower extremity strength, power, and flexibility [18]. There is a paucity of evidence in the literature evaluating the effect of TKD in young

children (<12 years). Considering the prevalence of obesity in this age group and the immediate need to prevent the lifelong complications associated with obesity, it is crucial to conduct a study in this age group.

The main objective of this pilot study was to evaluate the change in balance, lower extremity muscle power, and flexibility in children (6 – 12 years) with 10 weeks of TKD training. Secondarily, we wanted to evaluate the amount of physical activity during TKD. Also, we wanted to examine if children classified according to their body mass index (BMI) status had differences in balance, lower extremity power, and flexibility with 10 weeks of TKD training.

2 Methods

2.1 Participants

We conducted a quasi-experimental longitudinal study in which 17 children (7 female, 10 male), 6-12 years of age, enrolled in TKD classes, and their parents/guardians participated. Convenience sampling was used. The participants were recruited on a voluntary basis from a consenting TKD program in the community. Additionally, verbal assent from each child and written consent from parent/guardian was obtained prior to participation. This study was approved by the Institutional Review Board.

Height and weight (Health-O-Meter Professional Dial Scale, Sunbeam Products, Inc.) without shoes were measured to calculate BMI for each child. Determined on the basis of BMI, the total sample of participants was further classified into two groups: healthy weight (HW, $n = 11$), OW ($n = 6$). The CDC's BMI percentile Calculator for Child and Teen was used to calculate BMI [25]. Due to the small sample size, in this study please note that the OW group included children who are classified as OW and obese based on the BMI percentile calculator. Participant demographics are shown in Tables 1 and 2.

2.2 Protocol

Physical performance measurements were collected at baseline (Week 1) and following 10 weeks. Balance was measured using data obtained from an Advanced Medical Technology, Inc. (AMTI) portable force plate (Watertown, Mass.). Demonstrating good reliability and validity, this is a widely used clinical tool used to measure balance in children [21, 22]. The Just Jump System (Probotics, Inc, Huntsville, Alabama), a reliable and valid measure was used to test lower extremity power or lower body explosive strength by measuring VJ [26, 27]. The system consists of a hand held device, a connecting cable, and

a mat. The hand held device displays height in centimeters and hang time in seconds for one jump. A back-saver SR test was performed to test hamstring flexibility. The SR test was conducted by using the Acuflex I Flexibility Tester (SR box). The Back-saver SR test is a valid and reliable measure for measuring hamstring flexibility [28, 29]. Physical activity was measured using a Yamax SW-701 pedometer. Studies have reported the accuracy and validity of pedometers in determining the number of steps taken during physical activity in children [30]. Physical activity was assessed by calculating the average of each participant's number of steps taken over four TKD sessions.

Balance control was assessed under the following conditions: bipedal/normal stance eyes open (NSEO) and eyes closed (NSEC), tandem stance eyes open (TSEO) and eyes closed (TSEC), and single stance eyes open (SLEO) using calibrated force platforms. Each child was asked to remove socks and shoes. Dominance and preference of leg for tandem stance and single leg stance was determined. In the eyes open conditions, participants were asked to look at a target on the computer screen in front of them. In the eyes closed conditions, researcher observation was used to ensure compliance and absence of visual feedback system. Participants were asked to stand upright and as still as possible in a relaxed position with feet parallel with eyes open for a maximum duration of 30 seconds for NSEO, NSEC, TSEO, and TSEC. The criteria to terminate trial timing for SLEO included: movement of the supporting foot, hooking the free leg behind the supporting leg, dropping the free leg below 45 degrees of knee flexion, moving arms from their start position, tilting trunk, or looking away from the visual target. Adequate instructions and demonstration were provided prior to the measurements. All precautions were taken to minimize falls by providing supervision and guarding by researcher/student physical therapists. In between trials, participants were allowed an opportunity to refocus and step off the force platform. The following center of pressure (COP) variables were evaluated: displacement in mediolateral direction (X_{avg}), displacement in the anteroposterior direction (Y_{avg}) and average velocity (V_{avg}).

For measuring VJ, the child began by standing upright on the mat with feet shoulder width apart with shoes off. A researcher gave a demonstration and the participant followed by jumping straight up as high as they could without tucking their legs. The participant was informed that upon landing their feet should land simultaneously on the mat with no additional jumps once they had landed. The child had one practice trial followed by

three recorded runs. The average was taken with the three recorder runs.

A modified SR protocol was used to measure flexibility also called the back-saver [29]. The participant was given a demonstration by the researcher. The participant then sat at the SR box with one knee bent and foot flat against floor and the other leg extended on the ground with the bottom of their foot flat against the SR box. The participant then put one hand on top of the other, palms down and reached as far forward as they could keeping their back straight without lifting the extended knee off the ground. The final position was held for two seconds. The subject had one trial run and then each side (right and left) was measured three times. The recorded runs were then averaged for the right and left sides. The other researcher held the box to keep it steady so it did not move while another researcher took the measurement. Scoring was recorded to the nearest centimeter based on performance.

In order to measure physical activity during class sessions, pedometers were placed on the waistband of each participant by the researcher at the start of the TKD class. At the end of the class, researchers removed the pedometers and recorded the numbers of steps, as indicated by the pedometer.

To increase inter-rater reliability all researchers partook in multiple pilot testing sessions prior to the start of research in order to develop a systematic method for providing instruction and implementing procedures to be given to the participants during the data collection. All researchers administered the same test and measure when possible. All the test and measures were conducted in a randomized order.

2.3 Statistical Analysis

A 2-way ANOVA (time x group) with post-hoc testing was used to assess if 10 weeks of TKD had an effect on physical performance measures and to determine if there were differences in changes in physical performance measures with TKD training between HW and OW/obese groups. Physical activity levels comparing the two groups was determined using a non-parametric Mann Whitney U test. SPSS 21.0 was used to perform data analyses. The alpha level was set a priori at $P < 0.05$.

3 Results

Demographic information for all participants is presented in Table 1

3.1 Balance

There was an interaction effect seen between the two groups, HW and OW groups, and time (Tables 2a, 2b and 2c).

Table 1. Baseline demographics and measurements of participants represented with information for both girls (G) and boys (B) as well as healthy weight (HW) and overweight/obese (OW) groups

Category	Week 1 Mean \pm S.D.
Age, y	G: 7.9 ± 2.3 , B: 8.7 ± 1.4 HW: 8.8 ± 1.5 , OW/obese: 7.3 ± 2.0
Sex	G: 7, B: 10 HW: 11, OW/obese: 6
Height, cm	G: 134.2 ± 12.6 , B: 134.6 ± 9.6 HW: 134.8 ± 9.3 , OW/obese: 133.8 ± 13.5
Body mass index, kg/m ²	G: 20.0 ± 5.8 , B: 16.2 ± 3.8 HW: 15.5 ± 2.2 , OW/obese: 23.5 ± 5.3

Table 2a. The table depicts data for healthy weight (HW) and overweight/obese (OW) groups obtained under balance condition normal stance eyes open (NSEO) and normal stance eyes closed (NSEC) at baseline and 10 weeks. Corresponding *P* values are reported as time and group, with significance denoted by an asterisk (*) for the following variables: displacement of the center of pressure (COP) in mediolateral direction (X_{avg}), displacement of the COP in the anteroposterior direction (Y_{avg}), and average velocity (V_{avg}).

Condition	Variable	Baseline Mean \pm SD	10 weeks Mean \pm SD	<i>P</i> value time	<i>P</i> value group
NSEO	X_{avg} , cm	HW: 0.9 ± 0.4 OW: 1.4 ± 0.9	HW: 1.5 ± 0.3 OW: 0.4 ± 0.1	0.174	0.017*
	Y_{avg} , cm	HW: 9.5 ± 5.6 OW: 12.2 ± 4.6	HW: 10.5 ± 5.6 OW: 10.9 ± 4.1	0.003*	0.196
	V_{avg} , cm/s	HW: 6.9 ± 1.2 OW: 5.5 ± 1.2	HW: 7.1 ± 1.6 OW: 5.3 ± 1.4	0.884	0.002*
NSEC	X_{avg} , cm	HW: 1.5 ± 0.5 OW: 2.2 ± 1.1	HW: 1.0 ± 0.7 OW: 1.4 ± 1.0	0.913	0.152
	Y_{avg} , cm	HW: 13.0 ± 5.2 OW: 12.3 ± 4.1	HW: 10.4 ± 6.6 OW: 10.3 ± 3.4	0.005*	0.814
	V_{avg} , cm/s	HW: 8.5 ± 3.0 OW: 7.0 ± 1.2	HW: 8.1 ± 1.8 OW: 6.7 ± 2.0	0.289	0.043*

Table 2b. The table depicts data for healthy weight (HW) and overweight/obese (OW) groups obtained under balance condition tandem stance eyes open (TSEO) and tandem stance eyes closed (TSEC) at baseline and 10 weeks. Corresponding *P* values are reported as time and group, with significance denoted by an asterisk (*) for the following variables: displacement of the center of pressure (COP) in mediolateral direction (X_{avg}), displacement of the COP in the anteroposterior direction (Y_{avg}), and average velocity (V_{avg}).

Condition	Variable	Baseline Mean \pm SD	10 weeks Mean \pm SD	<i>P</i> value time	<i>P</i> value group
TSEO	X_{avg} , cm	HW: 1.3 ± 0.9 OW: 4.2 ± 2.3	HW: 1.1 ± 0.4 OW: 1.7 ± 0.8	0.355	0.509
	Y_{avg} , cm	HW: 9.1 ± 5.3 OW: 22.0 ± 5.7	HW: 11.2 ± 6.2 OW: 14.5 ± 5.7	0.101	0.005*
	V_{avg} , cm/s	HW: 11.5 ± 1.5 OW: 10.4 ± 1.3	HW: 11.4 ± 1.09 OW: 9.6 ± 1.05	0.726	0.04*
TSEC	X_{avg} , cm	HW: 2.3 ± 1.0 OW: 4.4 ± 3.0	HW: 0.6 ± 0.3 OW: 1.8 ± 1.0	0.639	0.072
	Y_{avg} , cm	HW: 8.3 ± 8.1 OW: 17.2 ± 7.1	HW: 6.5 ± 1.5 OW: 17.5 ± 4.5	0.281	0.000*
	V_{avg} , cm/s	HW: 14.7 ± 5.6 OW: 15.4 ± 4.7	HW: 17.2 ± 1.6 OW: 17.7 ± 1.5	0.179	0.651

Table 2c. The table depicts data for healthy weight (HW) and overweight/obese (OW) groups obtained under balance condition single leg eyes open (SLEO) at baseline and 10 weeks. Corresponding *P* values are reported as time and group, with significance denoted by an asterisk (*) for the following variables: displacement of the center of pressure (COP) in mediolateral direction (X_{avg}), displacement of the COP in the anteroposterior direction (Y_{avg}), and average velocity (V_{avg}).

Condition	Variable	Baseline Mean \pm SD	10 weeks Mean \pm SD	<i>P</i> value time	<i>P</i> value group
SLEO	X_{avg} , cm	HW: 1.3 ± 0.5 OW: 1.3 ± 0.6	HW: 0.6 ± 0.5 OW: 1.3 ± 0.8	0.635	0.783
	Y_{avg} , cm	HW: 2.6 ± 1.2 OW: 5.6 ± 4.3	HW: 0.76 ± 0.3 OW: 1.1 ± 0.7	0.030*	0.547
	V_{avg} , cm/s	HW: 8.1 ± 2.4 OW: 8.3 ± 2.8	HW: 10.5 ± 4.4 OW: 10.0 ± 3.4	0.023*	0.703

A significant time effect was noted with the Y_{avg} changing for both the HW and OW groups. A significant group effect was shown in the NSEO condition for V_{avg} ($P = 0.002$). For the NSEC condition, there was no interaction effect observed in any variables. A significant time effect was observed in the Y_{avg} changing in both groups. A group effect was also significant for V_{avg} ($P = 0.043$). For conditions with tandem stance, an interaction effect was detected for Y_{avg} ($P = 0.005$) in the TSEO condition. Additionally, a group effect was noted for V_{avg} ($P = 0.04$) in TSEO and Y_{avg} in TSEC ($P = 0.000$). For the SLEO condition a significant effect of time was noted for Y_{avg} and V_{avg} . No other significant effects were detected.

3.2 Lower extremity explosive strength

A significant between group effect for VJ distance ($P = .037$) was noted both at week 1 ($P = .037$) and week 10 ($P = .037$). See Figure 1. There was no interaction effect or effect of time for VJ.

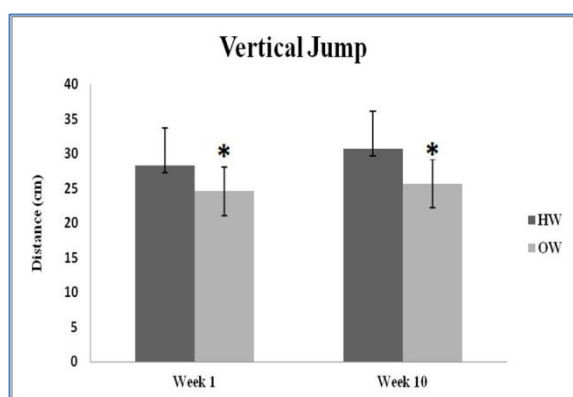


Figure 1. Vertical Jump Distance (cm) data for both healthy weight (HW) and overweight/obese (OW) groups at baseline (week 1) and 10 weeks (week 10). Corresponding P values are reported as between group effect with significance denoted by an asterisk (*).

3.3 Flexibility

For SR, which is a measure of flexibility, both groups showed a significant within group effect for time (SRL $P = 0.009$, SRR $P = 0.025$) (Figure 2). Results for SR demonstrated no interaction or group effects.

3.4 Steps Taken

The number of steps participants took during TKD sessions was measured using a pedometer. A non-parametric test showed there was no significant difference in the amount physical activity during TKD sessions as noted in the number of steps as measured by pedometer between the HW average number of steps (1736.1) and the OW average number of steps (1748.6) groups.

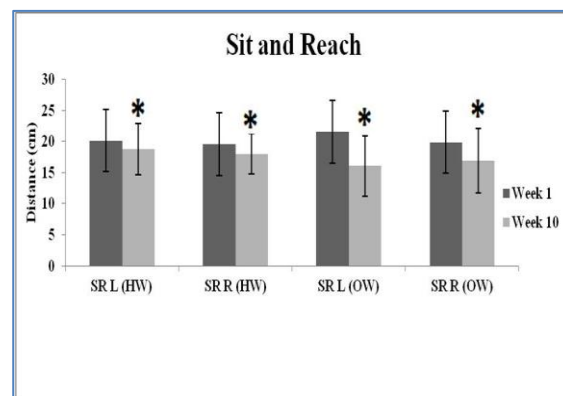


Figure 2. Sit and Reach data for both healthy weight (HW) and overweight/obese (OW) groups at baseline (week 1) and 10 weeks (week 10). Corresponding P values are reported as time effect with significance denoted by an asterisk (*).

4 Discussion

A quasi-experimental longitudinal study was used to primarily determine whether 10 weeks of TKD training had an effect on balance, lower extremity explosive power, and flexibility in children. Within this 10 week TKD training period, there was a significant improvement seen in certain measures of balance in the bipedal eyes open/closed and tandem stance eyes open conditions. There was a negative change in flexibility seen in both groups after 10 weeks of TKD.

4.1 Balance

The current study showed differences in postural sway between children who are HW and OW/obese over 10 weeks of TKD training. While both groups showed improvements in postural sway for bipedal and tandem stances, children who were OW/obese showed greater improvements in certain measures of balance.

Specifically for the NSEO condition, 10 weeks of TKD training improved static, bipedal balance for children aged 6-12 years, regardless of BMI and/or group classification. In the NSEO condition, children who were OW/obese showed greater improvements in mediolateral displacement and deviation of COP than the HW group on balance testing. McGraw et. Al found that children who are OW/obese may have less mediolateral postural stability due to the influence of body size and shape in relation the displacement of center of gravity [22]. Medi lateral stability is maintained through weight shifting at the hip joint. Increased body mass decreases the ability to weight shift laterally, thus influencing mediolateral stability. Furthermore, for children who are OW/obese, inherent challenges in this direction occur during the

gait cycle due to the narrowing base of support. In a study of prepubertal boys aged 8-10 years, results indicated boys who are OW/obese have decreased mediolateral stability and spend an increased amount of time in bipedal stance as compared to boys who are HW [22]. Therefore, decreased stability may be secondary to increased body mass. Our findings suggest that TKD could be used to improve mediolateral balance in children who are OW/obese. In addition to increased body mass, a previous study has shown that TKD practitioners demonstrate significantly decreased sway than non-practitioners of TKD [31].

When vision was challenged during the bipedal stance condition, the 10 week TKD training did not improve static standing balance for one group more so than the other. However, similar to the eyes open condition, balance measures for the displacement of center of pressure in the anteroposterior direction improved throughout the time period for both groups. Stability in the anteroposterior direction is maintained through muscular adjustments of lower extremity joints [22]. These findings partially support our hypothesis that TKD training can improve balance in bipedal stance through these muscular strategies. Research that shows TKD practitioners aged 11-14 years demonstrate increased sway when the visual system is eliminated, as compared to eyes open [19]. This supports our results which show that greater improvements are noted in bipedal stance eyes open versus eyes closed condition.

For tandem stance in the eyes open condition, postural sway showed greater improvements for the OW group than the HW group in the displacement and deviation of COP in the anteroposterior direction. Reported differences may be due to weight, indicating that BMI may have an effect on positioning in this condition. These findings suggest that children aged 6-12 years who are OW/obese may find a tandem stance difficult to perform. The tandem stance requires a narrow base of support with the participant having to position his or her feet in a vertical line with the back of heel touching the toes of the opposite foot. Primary stability in the anteroposterior direction during tandem stance occurs at the hip joint. With the hip joint having the largest degrees of freedom available, the knees and ankles are able to provide the body with secondary and tertiary strategies in order to maintain postural stability when compensating for increased mass or excess adipose tissue [22]. This may suggest that improvements in children may have occurred due to alterations in the hip strategy.

Furthermore, BMI has been found to be negatively correlated with gross motor coordination in children aged 6-12 years with a strong emphasis on children's weight status [32]. In TKD, participants perform techniques in a variety of lower extremity stances. While the tandem stance, as described, is not directly utilized in the sport, other stances require a decreased base of support and thus, challenge balance and vestibular systems. For example, performing a front kick requires a single limb base of support. Likewise, performing a spinning kick requires an additional challenge in order to maintain balance while having to pivot on the single-limb stance leg.

Significant differences in change in balance were not observed as frequently in the tandem stance eyes closed and single leg stance conditions. Balance improved in the single leg stance for velocity and measures of direction for both groups, suggesting TKD improves balance for children who are HW and OW/obese. TSEC and SLEO tasks required both groups to maintain a narrow base of support, postural reactions and/or joint positioning. Frequent jumping, weight shifting, and spinning kicks performed in TKD training may help to stimulate the development of the vestibular systems [33]. Furthermore, TKD training decreases the velocity of sway in single leg stance secondary to increased performance of vestibular system as compared to age-matched non-TKD adolescents [19]. These improvements are consistent with the single leg balance improvements seen in another study where a decrease in sway and an increase in stance time were noted [34]. With data being similar amongst both groups for these conditions, it is possible the participants had increased difficulty initially assuming the position and subsequently maintaining the stance secondary to balance and/or strength deficits [21]. Additional factors that should not be overlooked include familiarity with testing especially in challenging conditions for children. Having a higher degree of difficulty, the SLEO condition could have improved in both groups due to a familiarity effect with the testing procedure. These categories consisted of more difficult tasks for this age group, possibly contributing to lack of difference between the two groups.

4.2 Lower extremity explosive strength

Children who are OW/obese have shown to have decreased lower extremity explosive power than those children who are HW [23, 24, 35]. In this study, at baseline the HW group demonstrated a 3.6 cm greater VJ distance as compared to the OW group and at week 10 the HW group had a 5.0 cm greater VJ distance as compared to the OW group, which was proven statistically significant. This could be

explained secondary to the excessive body mass with children who are OW. The distance jumped is related to the child's muscle action working against the child's body mass resistance. Therefore theoretically, the higher the body mass, the less they will be able to jump. Also, if a child's initial speed of acceleration, which is correlated to force and mass, is decreased secondary to body weight then they will not be able to jump as high. In order for a child who is OW to have the same VJ distance as a child who is HW, the child who is OW must have a greater force while pushing off the floor to equal the same acceleration as a child who is HW [36].

Additionally, with 10 week of TKD, both groups showed improvements in VJ distance but this was not statistically different. These findings do not concur with a study conducted in female TKD athletes that compared top competitors and have won medals with another group of female TKD athletes that are not as competitive and have not won any medals. The group that had the top competitors had greater lower extremity explosive power than the other group indicating that explosive power is an important aspect of TKD [37]. Other data show gender differences with boys (age 13-14 yrs) noting improvement from their pre TKD completion to their post TKD competition scores for lower extremity explosive power while females showed no change [38]. The current study did not test VJ before and after competitions, but both girls and boys in the study improved their VJ distance from week 1 to week 10. The lack of statistical differences in this current study could be attributed to the small sample size.

4.3 Flexibility

For SR both groups, HW and OW/obese showed a significant within group difference following 10 weeks of TKD, demonstrating that TKD may have had an effect on the children's flexibility. Contrary to balance and lower extremity power, multiple studies have suggested that the child's overall flexibility is not altered based on excessive adipose tissue [39, 40]. This may explain the results of our study, which indicate that there were no significant between group changes in flexibility after 10 weeks of TKD.

Interestingly, although a change in flexibility was noted, it was a negative change, which in turn means that over the course of 10 weeks of TKD both groups flexibility decreased. From all the participants, only four demonstrated increases in flexibility, all which were in the HW group. Those who demonstrated increases in flexibility on average gained 1.88 cm, whereas those children who decreased in flexibility on average decreased 3.89 cm with the HW group experiencing an average decrease

of 3.21 cm and the OW/obese group experiencing an average decrease of 5.08 cm.

It is unclear as to why flexibility decreased in both groups following 10 weeks of TKD. It is possible that the decrease in flexibility may have also been due to the child already attempting the SR once before during week 1 measurements and therefore not attempting to get the highest number as possible during week 10 measurements. Additionally, a modified SR test was used for this study, as compared to a standard SR test. Our results do not correspond with the literature that suggests improvements in flexibility with TKD in older age groups [37, 41- 43].

4.4 Pedometers

In this study the pedometers intended to measure the number of steps in a TKD session. The pedometers were used to determine if the amount of physical activity differed in the HW versus OW group. The same number of steps taken in the groups suggests TKD encourages similar levels of physical activity for children who are HW and OW/obese. This is clinically important as activities that allow children in all BMI groups to be engaged to a similar extent are needed to prevent childhood obesity.

4.5 Limitations

The main limitation of this study is that there was no control group, which challenges the internal validity. Other limitations of this study include a small sample size and a small number of children who were in the OW/obese category. Age, belt rank, and experience in TKD could have contributed to differences in data results. Time of testing (before/after class, no class on testing day) could have contributed to differences and was not taken into account. As noted previously, future studies should aim to include novice white belts. These studies may want to break down physical performance levels based on belt rank to determine if there are differences noted between the groups.

5 Conclusions

This is the first study that evaluated the effect of TKD training on physical performance measures in children 6- 12 years of age. Since the data has established that children aged 6-19 years of age have increased odds of developing obesity, it is essential to target this age range to prevent further development of obesity and decrease current trends. The data from the current pilot study suggest significant improvements in certain variables of balance especially in the bipedal stance with 10 weeks of TKD training. Though improvements were noted in the LE power with TKD training these changes

were not significant. These findings point towards a role for TKD training to improve physical performance in children after school, especially those who are OW/obese.

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Competing Interests:

The authors declare that they have no competing interests.

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