**ORIGINAL ARTICLE**

**Taekwondo Training Has Long-term Beneficial Effects on Bone Mineral Density and Physical Fitness in Middle-Aged Men**

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**Abstract**

This study examined the long-term effects of Taekwondo training on bone mineral density (BMD), body composition, and physical fitness in middle-aged men. Thirty men (43 ± 2 yr) were divided into three groups based on Taekwondo experience and current training volume. The currently practicing Taekwondo group (TKDC: n = 10, training career: 34.1 yr) practiced Taekwondo ≥ 2 times per week. The former Taekwondo group (TKDS: n = 10, training career: 19.2 yr) trained during childhood and adolescence, but ceased training before age 30. The control group (CON: n = 10) received no regular physical training during youth. The results showed that both Taekwondo groups had a significantly higher BMD, (p < 0.004) and Z-scores (p < 0.008) for femoral neck and L4 BMD (p < 0.023). For physical fitness, both groups showed significantly better results for 50m shuttle run (p < 0.001) and sit-ups (p < 0.0004) than the control group. No significant difference was found in body composition among the groups. In conclusion, TKDC and TKDS may have had site-specific benefits for BMD. As there was no significant difference in these variables between the two Taekwondo groups, the benefits were most likely gained during childhood and adolescence, and further training did not appear to increase these gains. More research is needed with a larger sample size to confirm these findings.

**Introduction**

A physically active lifestyle has a number of health benefits in regards to body composition (23), bone mineral density (BMD) (1, 19, 24), and physical fitness (10) when compared to a sedentary lifestyle. These benefits can affect all stages of life, improve quality of life, and even decrease mortality (26). A number of studies have shown that regular physical activity during childhood and adolescence can have a positive effect on former athletes’ health even after training volume has decreased or even ceased completely (26, 30, 31).

Physical activity has been correlated with higher BMD (31). The specific type of exercise optimal for improving BMD is still being debated. The bone remodeling process is site specific, as shown by different BMD in dominant and non-dominant hands in sedentary participants (17) and positive responses in cortical bone in the playing arm of young tennis players (7). A study investigated the benefit of site-specific high-impact-jump training to reduce osteoporotic fracture risk and concluded that jumping-hopping-training was the most effective method to increase femoral neck and lower neck BMD of the trained leg (1). This implies that site-specific high-impact exercise is optimal for increasing the bone remodeling process.

Several studies have examined the effects of a detraining period on elite athletes’ BMD and found that BMD is well maintained after termination of physical activity (20, 21, 31). Through periods of detraining ranging from 5–12 yr, athletes in various sports maintained higher BMD than sedentary control groups (8, 19, 24, 30). Kontulainen et al. (19) compared young and old tennis players and found greater gains in the young starters, highlighting the importance of early participation in physical activity. Former professional American football players who competed on the 1958...
World Champion Colts team or other professional National Football League teams had higher BMD and bone mineral content (BMC) at all sites than in controls (21).

Physical fitness has been defined as “the ability to carry out daily tasks with vigour and alertness, without undue fatigue and with ample energy to enjoy [leisure] pursuits and to meet unforeseen emergencies” (11). Physical fitness is often measured by cardiorespiratory fitness using a maximal graded exercise test that measures maximal oxygen uptake (VO2max). Studies have found that increasing physical fitness and physical activity can have a positive effect on longevity by reducing mortality from a number of causes, especially cardiovascular disease (10). Endurance exercise is generally thought to be optimal for improving cardiovascular fitness. Although cardiovascular fitness responds quickly to training and detraining, studies have found that former athletes in endurance sports, Olympic endurance sports athletes for example (26), had longer life spans than the general population.

Taekwondo is classified as a martial art and an Olympic sport. Training is mainly comprised of poomsae (pre-established routines of offensive and defensive techniques), sparring, and a strong focus of kicks, which score the majority of points in sparring competition (13). Successful elite Taekwondo athletes have high lower limb strength (12). Taekwondo is a popular sport in many countries, and it is marketed primarily towards young children, especially in Korea. Participation is strongest during elementary school, declines towards the end of university life, and very few adults participate in Taekwondo (3).

Most studies into the effects of Taekwondo have been conducted on current athletes or how it is used as an intervention program. Taekwondo training improves isokinetic strength, physical fitness, and body composition in sedentary high school girls (15), and high school Taekwondo athletes had higher lumbar and femur BMD than age matched controls (29). Professional and youth Olympic athletes had low percentage body fat and body mass indexes (BMI), and higher lean mass than non-winners (13, 14). Taekwondo athletes from the Czech national team had lower than average adiposity as well as above-average muscular strength, flexibility, and aerobic power (12).

Therefore, the aim of this study was to determine if gains in BMD, muscle strength, and physical fitness obtained during early participation in Taekwondo training persist into later life by comparing those who are still practicing Taekwondo to those who have ceased their Taekwondo careers and a sedentary control group whose members had no former training experience. We hypothesized that prior and current Taekwondo training has beneficial effects on bone mineral density and physical fitness in middle-aged men.

Methods

Subjects

Thirty men aged 42.8 ± 2.09 yr participated in this study. They were recruited through telephone calls to Korea Taekwondo Association and in response to poster advertisements. They were classified into three groups based on Taekwondo experience and current training volume: currently practicing Taekwondo group (TKDC: n = 10), former Taekwondo group (TKDS: n = 10), and control group (CON: n = 10).

The inclusion criteria were 1) males aged 40 yr or older, 2) the Taekwondo group needed to have practiced and participated for competition during youth, and 3) the control group should not have a previous history of exercise training. Taekwondo training is defined as a structured exercise program which involves warm-up (static stretching), main exercise (stepping, punching, kicking, and sparring), and cool down (meditation and stretching) periods. The exclusion criteria were subjects 1) who have participated or who are currently participating in other sports or exercise programs, and 2) participants with musculoskeletal disorders such as tendinitis, rheumatoid arthritis, and bone fractures.

The Taekwondo groups were classified as currently active (TKDC) or currently sedentary (TKDS) as a result of their questionnaire answers. TKDC participants were reportedly still practicing Taekwondo (≥ 2 times per week), and TKDS participants were currently sedentary according to metabolic equivalent (MET) values calculated from International Physical Activity Questionnaire (IPAQ) answers and self-reported cessation of personal Taekwondo training). The IPAQ and calculation of MET were described by Craig et al. (4). TKDC athletes (TKDC) practiced Taekwondo 5–6 times per week during childhood and adolescence, and were still practicing Taekwondo ≥ 2 times per week. TKDS also participated in regular Taekwondo training 5–6 times per week during childhood to adolescence, but finished training before the age of 30. These groups were matched for age and BMI to the currently sedentary control group (CON), who did not participate in regular physical activity when they were young with the exclusions of school physical education classes and
Conscripted military training. Participants were excluded if they had participated or were currently participating regularly in other sports or exercise programs. All participants completed an informed consent form and were free to withdraw at any time with no disadvantage. All procedures described above were approved by the International Review Board at Kyung Hee University (KHSIRB-15-012).

All testing was performed between 0900h and 1900h in the laboratory. Prior to the tests, all participants limited their intense physical activity for the last 24 hours. The measurements were carried out twice according to protocol in light clothing. Body height was measured using a stadiometer (T.K.K. 11253, Takei Scientific Instruments Co., Japan) in a standard upright posture without shoes and recorded to the nearest 0.1cm. Body mass was measured using a standard digital weight scale (Cas 150A, Korea) and recorded to the nearest 0.1kg. BMI was calculated from body height and mass using the following equation:

\[
\text{BMI} = \frac{\text{mass (kg)}}{\text{height}^2 (m^2)}
\]

Waist and hip circumference were measured with a measuring tape. These results were recorded to the nearest 0.1 cm. These measurements were used to calculate waist to hip ratio (WHR) using the following equation.

\[
\text{WHR} = \frac{\text{waist circumference (cm)}}{\text{hip circumference (cm)}}
\]

**Body composition and bone mineral density**

Body composition parameters including fat mass, percent body fat, lean mass, BMD, and BMC were assessed using Dual X-ray Absorptiometry (DXA: Hologic, QDR-4500W, USA). BMD was evaluated at three different sites (whole body, proximal femur, and lumbar spine) by DXA and recorded in g/cm². All scans were recorded and analyzed by the same technician.

**Physical fitness**

The physical fitness variables included balance, flexibility, static muscle strength, agility, power, muscular endurance, and aerobic capacity as described by Morrow et al. (22).

**Balance test**

Balance was assessed by the Flamingo Balance Test.

Participants stood on a standard beam on their preferred leg, with the other leg flexed at the knee and their foot held close to the buttocks while holding the assistant’s shoulder. The assistant started the stopwatch as soon as the participant let go of their shoulder. The number of falls in 60 seconds was recorded.

**Flexibility test**

Flexibility was assessed by sit and reach tests using a digital measure bar (DAC: Donghwa Athletic Corporation, South Korea). Participants were seated on the floor with their feet touching the vertical board, legs fully extended. They placed one hand on top of the other and pushed the reader as far along the horizontal measure as possible with their legs remaining straight throughout the duration of the test. The test was performed twice, and the better of the two values was used for analysis. The score was recorded to the nearest 0.01cm.

**Static muscle strength**

Muscle strength is usually defined as the amount of muscle tension/force generated by a muscle at a given length and is defined as the maximal isometric tension or force generated at that point. To measure the maximum isometric strength of the hand and arm muscles, a handgrip dynamometer (T.K.K. 5001, grip-D Takei, Tokyo, Japan [Takei Scientific Instruments Co., Ltd]) was used. The subjects held the dynamometer in their preferred hand with their arms at right angles and elbows by the side of their bodies. The participant squeezed the dynamometer with maximum isometric effort on command and maintained their grip for about 5 seconds. Each participant was allowed two attempts, which were recorded in kg, and the higher score was used for analysis.

**Agility**

Agility was assessed using the 50m shuttle run test. Participants were timed running to and from markers 5m apart 5 times without stopping (covering 50m total). Both feet were required to have fully crossed the line at each marker. The total time taken to complete the 50m course was recorded to the nearest 0.01 second.

**Power**

Power was assessed using the standing long jump test. The participants stood behind a line marked on the floor, feet slightly apart. Using a two-foot takeoff and landing
while swinging arms and bending at the knees to provide forward drive, the subjects jumped forward as far as possible.

The measurement was taken from the takeoff line to the nearest point of contact on landing, from the back of the heels. Two attempts were allowed and the longer distance was used for analysis.

Muscular endurance

Muscular endurance was measured by the number of sit-ups performed within 60 seconds. The participants laid on a mat, their knees were bent at 90° with their feet flat on the floor secured by a partner. This was repeated for 60 seconds, and the maximum number of correctly performed sit-ups performed was recorded.

Aerobic capacity

Aerobic capacity was measured using a maximal graded exercise test with the Bruce Protocol.

Statistical analysis

Data was analyzed using SAS Version 9.4. A power analysis indicated that the remaining participants (TKDC: n = 10, TKDS: n = 10, CON: n = 10) achieved a statistical power of 0.80 with effect size of 0.6. Data was presented as mean ± standard deviation (SD). One-way analysis of variance (ANOVA) was used to determine differences among the three groups (TKDC, TKDS, and CON). Significant difference was found in a post hoc test using Duncan’s Multiple Range test. The level of significance was set at p < 0.05.

Results

Anthropometry

Table 1 indicates the anthropometric characteristics of the participants in the three groups. There was no significant difference among the groups for any of the variables. The intended demographic for this study was middle-aged men (TKDC: 43.2 ± 2.44 yr, TKDS: 41.8 ± 2.04 yr, CON: 43.3 ± 1.42 yr).

Body composition

The results for body composition can be found in Table 2. No significant difference was found among the

<table>
<thead>
<tr>
<th>Variables</th>
<th>TKDC (n = 10)</th>
<th>TKDS (n = 10)</th>
<th>CON (n = 10)</th>
<th>F-value</th>
<th>Prob &gt; F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Percent Body Fat (%)</td>
<td>23.1 ± 3.96</td>
<td>19.4 ± 4.83</td>
<td>22.9 ± 4.78</td>
<td>2.11</td>
<td>0.141</td>
</tr>
<tr>
<td>Fat Mass (kg)</td>
<td>18.0 ± 4.35</td>
<td>14.7 ± 4.93</td>
<td>17.2 ± 5.08</td>
<td>1.25</td>
<td>0.304</td>
</tr>
<tr>
<td>Lean Mass (kg)</td>
<td>57.0 ± 5.19</td>
<td>57.1 ± 4.36</td>
<td>53.9 ± 6.13</td>
<td>1.21</td>
<td>0.315</td>
</tr>
</tbody>
</table>

TKDC: currently practicing Taekwondo group; TKDS: previously practiced Taekwondo, currently sedentary group; CON: control group (no Taekwondo experience).
Table 3. Comparison of bone mineral density (BMD) among the three groups (Mean ± SD)

<table>
<thead>
<tr>
<th>Variables</th>
<th>TKDC (n = 10)</th>
<th>TKDS (n = 10)</th>
<th>CON (n = 10)</th>
<th>F-value</th>
<th>Prob &gt; F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Whole body BMC (g)</td>
<td>2652.3 ± 489.95(^A)</td>
<td>2753.4 ± 343.47(^A)</td>
<td>2557.0 ± 338.73(^A)</td>
<td>0.61</td>
<td>0.550</td>
</tr>
<tr>
<td>Whole body BMD (g/cm(^2))</td>
<td>1.22 ± 0.13(^A)</td>
<td>1.26 ± 0.07(^A)</td>
<td>1.16 ± 0.07(^A)</td>
<td>2.80</td>
<td>0.079</td>
</tr>
<tr>
<td>Whole body Z-Score</td>
<td>0.80 ± 1.43(^A)</td>
<td>1.35 ± 0.75(^A)</td>
<td>0.26 ± 0.79(^A)</td>
<td>2.77</td>
<td>0.080</td>
</tr>
<tr>
<td>Femur BMD (g/cm(^2))</td>
<td>0.98 ± 0.13(^A)</td>
<td>1.03 ± 0.09(^A)</td>
<td>0.93 ± 0.11(^A)</td>
<td>2.09</td>
<td>0.143</td>
</tr>
<tr>
<td>Femur Z-Score</td>
<td>0.63 ± 0.91(^A)</td>
<td>0.91 ± 0.69(^A)</td>
<td>0.19 ± 0.79(^A)</td>
<td>2.04</td>
<td>0.149</td>
</tr>
<tr>
<td>Femoral neck BMD (g/cm(^2))</td>
<td>0.91 ± 0.12(^A)</td>
<td>0.98 ± 0.09(^A)</td>
<td>0.81 ± 0.08(^B)</td>
<td>6.79</td>
<td>0.004</td>
</tr>
<tr>
<td>Femoral neck Z-Score</td>
<td>1.09 ± 1.01(^A)</td>
<td>1.50 ± 0.70(^A)</td>
<td>0.29 ± 0.68(^B)</td>
<td>5.78</td>
<td>0.008</td>
</tr>
<tr>
<td>Lumbar BMD (g/cm(^2))</td>
<td>1.02 ± 0.19(^A)</td>
<td>1.07 ± 0.06(^A)</td>
<td>0.95 ± 0.10(^A)</td>
<td>2.18</td>
<td>0.132</td>
</tr>
<tr>
<td>Lumbar Z-Score</td>
<td>0.30 ± 1.35(^A)</td>
<td>0.62 ± 0.43(^A)</td>
<td>-0.15 ± 0.67(^A)</td>
<td>1.84</td>
<td>0.178</td>
</tr>
<tr>
<td>L1 BMD (g/cm(^2))</td>
<td>0.97 ± 0.16(^A)</td>
<td>0.99 ± 0.07(^A)</td>
<td>0.90 ± 0.08(^A)</td>
<td>1.89</td>
<td>0.171</td>
</tr>
<tr>
<td>L1 Z-Score</td>
<td>0.59 ± 1.14(^A)</td>
<td>0.77 ± 0.47(^A)</td>
<td>0.16 ± 0.25(^A)</td>
<td>1.60</td>
<td>0.221</td>
</tr>
<tr>
<td>L2 BMD (g/cm(^2))</td>
<td>1.04 ± 0.18(^A)</td>
<td>1.08 ± 0.08(^A)</td>
<td>0.96 ± 0.10(^A)</td>
<td>2.48</td>
<td>0.102</td>
</tr>
<tr>
<td>L2 Z-Score</td>
<td>0.61 ± 1.28(^A)</td>
<td>0.93 ± 0.57(^A)</td>
<td>0.09 ± 0.74(^A)</td>
<td>2.15</td>
<td>0.136</td>
</tr>
<tr>
<td>L3 BMD (g/cm(^2))</td>
<td>1.04 ± 0.22(^A)</td>
<td>1.10 ± 0.09(^A)</td>
<td>0.98 ± 0.11(^A)</td>
<td>1.48</td>
<td>0.245</td>
</tr>
<tr>
<td>L3 Z-Score</td>
<td>0.24 ± 1.58(^A)</td>
<td>0.71 ± 0.62(^A)</td>
<td>-0.10 ± 0.81(^A)</td>
<td>1.41</td>
<td>0.262</td>
</tr>
<tr>
<td>L4 BMD (g/cm(^2))</td>
<td>1.04 ± 0.22(^A)</td>
<td>1.09 ± 0.08(^A)</td>
<td>0.46 ± 0.90(^B)</td>
<td>4.32</td>
<td>0.024</td>
</tr>
<tr>
<td>L4 Z-Score</td>
<td>-0.06 ± 1.53(^A)</td>
<td>0.29 ± 0.55(^A)</td>
<td>-0.55 ± 0.79(^A)</td>
<td>1.63</td>
<td>0.214</td>
</tr>
</tbody>
</table>

Means with the same letter (\(^A\) or \(^B\)) are not significantly different among the groups.

TKDC: currently practicing Taekwondo group; TKDS: previously practiced Taekwondo, currently sedentary group; CON: control group (no Taekwondo experience); BMC: bone mineral content; BMD: bone mineral density; L1: lumbar 1; L2: lumbar 2; L3: lumbar 3; L4: lumbar 4.

Table 4 indicates the results for physical fitness. Significant differences among the groups were found for 50m shuttle run (F = 9.021, p < 0.001) and sit-ups (F = 10.65, p < 0.0004). Both Taekwondo groups performed significantly better in the 50m shuttle run and sit-ups tests than the control group. The results for the other tests did not significantly differ among the groups.

**Discussion**

This was most likely the first study examining the effects of early participation in Taekwondo training on BMD, body composition, and physical fitness in current and former practitioners. The main findings of this study
were that both Taekwondo groups had higher femoral neck BMD, L4 BMD, and Z-scores than the control group. For physical fitness, both Taekwondo groups performed significantly better in the 50m shuttle run and sit-ups.

The current study also found no difference in lean or fat mass among the three groups. However, percent body fat (19.4% - 23.1%), fat mass (14.7kg – 18.0kg), and lean mass (53.9kg – 57.0kg) for our subjects were in the recommended ranges. Body composition can be affected by a number of factors, such as genetics, age, and calorie intake as well as volume and type of exercise (6). Participants in the current study were matched for age, and their weekly MET values were used to determine levels of physical activity. A former study using a 12-month training program followed by a 6-month detraining period found that body composition of the exercise group reverted to baseline levels following the detraining period (32). In the current study, TKDS experienced a significantly longer detraining period, and TKDC were currently training at a lower volume than during youth, which may account for the lack of difference among the groups for body composition. Conflicting results have been found with former football athletes retaining a greater muscle mass and lower fat mass than controls (21), but this may be explained by higher levels of weekly METs in the football group than the control group. Diets low in sodium and empty calories positively affect body composition, and diets high in protein intake were related to a higher risk of becoming overweight or obese (5). As the current study did not include a food diary, calorie intake, or quality of diet, those may be responsible for the lack of significant difference in body composition among the groups. It is possible that the current samples were not receiving a high enough quality of diet to affect body composition positively.

In support of our hypothesis, significantly higher BMD (p < 0.004) and Z-scores (p < 0.007) were found, specifically in the femoral neck region in TKDC and TKDS as compared to CON. No significant differences were found for whole body BMD or Z-scores among the groups. Also, L4 BMD was significantly higher in both TKDC and TKDS than CON (p < 0.023). This can be explained by the fact that participants in Taekwondo training perform various kicks combined with stepping, jumping, and turning movements, which may lead to greater L4 BMD and femoral neck BMD. Previous studies have found that BMD is maintained in former athletes after varying lengths of detraining periods. Following a 4-yr retirement period, former gymnasts maintained significantly higher total body, femoral neck, Ward’s triangle, and greater trochanter BMD compared to a control group (20). After 5 yr of reduced training or a detraining period a similar result was seen in tennis and squash players (19). In a longer follow-up study, Tervo et al. (30) found that badminton players maintained higher BMD than hockey players and the control group. These results support the current findings of higher BMD in specific sites in the Taekwondo groups following decreased or complete cessation of training.

The current study’s findings in femoral neck BMD can be explained by the site-specific nature of bone formation. TKDC and TKDS both began their careers

<table>
<thead>
<tr>
<th>Variables</th>
<th>TKDC (n = 10)</th>
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<th>CON (n = 10)</th>
<th>F-Value</th>
<th>Prob &gt; F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flamingo Balance Test (n)</td>
<td>10.9 ± 5.50A</td>
<td>10.3 ± 4.24A</td>
<td>13.51 ± 5.76A</td>
<td>1.07</td>
<td>0.356</td>
</tr>
<tr>
<td>Sit &amp; reach (cm)</td>
<td>17.6 ± 7.8A</td>
<td>12.8 ± 12.24A</td>
<td>7.3 ± 11.62A</td>
<td>2.29</td>
<td>0.120</td>
</tr>
<tr>
<td>Grip strength (kg)</td>
<td>46.3 ± 6.42A</td>
<td>46.3 ± 6.56A</td>
<td>45.9 ± 6.97A</td>
<td>0.01</td>
<td>0.990</td>
</tr>
<tr>
<td>50m shuttle run (sec)</td>
<td>21.0 ± 1.12A</td>
<td>20.4 ± 1.52A</td>
<td>23.2 ± 1.85B</td>
<td>9.02</td>
<td>0.001</td>
</tr>
<tr>
<td>Standing long jump (cm)</td>
<td>209.0 ± 14.71A</td>
<td>219.2 ± 12.56A</td>
<td>204.3 ± 13.86A</td>
<td>3.09</td>
<td>0.062</td>
</tr>
<tr>
<td>Sit-ups (n)</td>
<td>41.5 ± 9.21A</td>
<td>42.8 ± 9.27A</td>
<td>25.2 ± 10.01B</td>
<td>10.65</td>
<td>0.0004</td>
</tr>
<tr>
<td>VO2max (ml/kg/min)</td>
<td>39.8 ± 5.20A</td>
<td>40.1 ± 9.71A</td>
<td>40.1 ± 4.38A</td>
<td>0.01</td>
<td>0.995</td>
</tr>
</tbody>
</table>

Means with the same letter (A or B) are not significantly different among the groups. TKDC: currently practicing Taekwondo group; TKDS: previously practiced Taekwondo, currently sedentary group; CON: control group (no Taekwondo experience).
during childhood or adolescence; therefore, their training would have extended over puberty and skeletal maturation. During this time pubertal androgen production is responsible for increasing periosteal apposition, bone diameter, and cortical thickness (28). As there was no significant difference between TKDC and TKDS, the gains were most likely obtained during youth. High-school athletes practicing Taekwondo (29) as well as other martial arts, for example judo (17), had higher BMD at the lumbar, femur, and forearm than sedentary controls. Kontulainen et al. (19) reached a similar conclusion to the current study based on their observation that younger starting racket sport players had greater BMC in the humeral shaft gains even following reduced training. The results of the current study combined with those of former studies highlight the importance of early participation in physical activity for obtaining high BMD.

The increase in BMD in response to physical activity is site specific as can be shown by sport specific gains as well as even gains in the dominant hand of sedentary participants (17) and in the playing arm of tennis players (7). The nature of Taekwondo competition relies strongly on kicks, during which the femoral neck of the standing leg is responsible for holding the majority of the body’s mass as well as receiving impacts following jumping kicks. During competition and training, kicks are rarely executed from a static position, but with a constant stepping motion combined with forwards and backwards sliding (16). A study examining high-impact jump training found increased femoral neck BMD in previously sedentary participants (1). This type of motion is similar to Taekwondo; therefore, those results are consistent with the current study’s finding of higher femoral neck BMD in the current and former Taekwondo participants.

Despite higher BMD values for the femoral neck and L4, BMD and Z-scores were not significantly different among groups for the whole body. These findings suggest that Taekwondo training had a site-specific effect. However, this was not enough to have an effect on the whole body. The results correlate to a former study for BMD of retired football (soccer) players that found significant differences at only the weight loaded sites following retirement of at least 10 yr (31). That study cited Karlsson’s hypothesis, which states that during physical training the weight loaded sites gain higher BMD, the partially loaded sites will not differ in BMD, and the unloaded regions will have lower BMDs when compared to a non-training control group. In the current study this could explain why, despite higher femoral neck BMD, the Taekwondo groups did not have significantly higher whole body BMD than the control group.

The current study found significant differences among the three groups for some of the physical fitness variables. The Taekwondo groups (TKDC and TKDS) performed significantly better in sit-ups in 60s (p < 0.0004) and the 50m shuttle run (p < 0.001) than the control group. These results correlate to those found in previous studies (2, 18). A number of other studies have been conducted on the effects of Taekwondo as an intervention on previously untrained subjects. Following 12 weeks of Taekwondo training, Kim and Khil (18) found a higher percentage increase in the number of sit-ups in the training group compared to the control group. Another study into health related physical fitness of martial arts practitioners found the majority performed ‘above average’ or ‘well above average’ for the abdominal muscular endurance test, yet 39.4% of the Taekwondo practitioners fell into the latter category (27). One explanation for the current study’s findings is that Taekwondo training activates the abdominal muscles during kicking to aid with balance controlling the backward pull of gravity (9). An alternative explanation considers the nature of the traditional sit-up test. During this test, the participants’ feet were secured by a partner, in accordance with the European Fitness Test procedure. A previous study suggests that performing a full sit-up in this position engages the abdominals significantly less than un-held sit-ups and that during the final stages of a full sit-up the hip flexors are performing the majority of the work (25). Therefore, higher results from Taekwondo participants in this test may be due to superior hip flexor muscles resulting from use while kicking (9). When executing Taekwondo kicks, hip activation is important for the rotation needed to achieve the correct angle as well as controlling distance (16).

The Taekwondo groups (TKDC and TKDS) also performed significantly better on the agility test, which was measured by a 50m shuttle run. Agility is important to Taekwondo athletes, as during competition their area of movement is limited to an 8m by 8m ring. Bridge et al. (2) conducted a meta-analysis of physical and physiological characteristics of Taekwondo athletes, and based on their findings of the superior agility of medalists compared to non-medalists, concluded that agility is an important aspect for success. One explanation considers the possibility of genetic differences between the Taekwondo groups and control. The Taekwondo groups could have high fitness levels genetically, which would allow them to excel in their sport. It consequently might have been this natural ability that allowed them to perform better rather than the training they did years ago.
There was a slight but statistically insignificant difference between the Taekwondo groups (TKDC and TKDS) and the control group for standing long jump (TKDC: 209.00 ± 14.71 cm, TKDS: 219.24 ± 12.56 cm, CON: 204.30 ± 13.86 cm), flexibility (TKDC: 17.55 ± 7.8 cm, TKDS: 12.77 ± 12.24 cm), and balance (TKDC: 10.90 ± 5.50, TKDS: 10.30 ± 4.24, CON: 13.50 ± 5.76). However, none of these scores reached the significant level of p < 0.05. The current sample size was small, so clearer results may be elicited with a larger sample. There was no difference among the three groups for grip strength. Due to the strong focus on kicks in Taekwondo competition (13, 14), much of Taekwondo training focuses on lower limb strength and flexibility. A previous study reported inferior grip strength in Taekwondo practitioners as well as those who participate in other striking arts, and it concluded that it was a result of similar motions to the grip strength test not appearing in their training (27).

Conclusions

The purpose of this study was to examine the long-term effects of prior or current Taekwondo training on body composition, bone health and physical fitness. There were two main results of the study. First, participants who had participated in Taekwondo training (TKDC and TKDS) had significantly higher femoral BMD and Z-scores as well as and higher L4 BMD than participants in the control group. Second, for physical fitness, the Taekwondo groups (TKDC and TKDS) had superior scores for agility (50m shuttle run) and muscular endurance (sit-ups).

The results of the study imply that Taekwondo training had a site-specific positive osteogenic effect for participants in the current study. The lack of difference between the two Taekwondo groups suggests that these benefits may have been received during childhood and adolescence when training volume was highest, and that further training (after the age of 30) may not have had much effect. This highlights the importance of early participation in Taekwondo training. The results also suggest that Taekwondo training had a similar effect on physical fitness in the current sample. More research is needed in this area with either a larger sample size or as a longitudinal study to confirm these findings.

Study limitations

The limitations of the study are as follows. Based on the desired demographic, the sample size was small (30 participants) due to the difficulty locating former and current Taekwondo players. As the sample consisted of men aged between 40 and 50, the results will be only applicable to this demographic. Dietary information and physical activity outside of Taekwondo that could have caused the differences between groups with regard to body composition and bone mineral density were not collected.

References

10. Faff J. Physical Activity, physical Fitness, and


