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Original Article

Comparison of gait features, balance ability, and reaction time between young female sedentary individuals and state-level netball players

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Abstract:
Background: This study investigated the differences of gait features, balance ability, and reaction time (RT) between sedentary controls and netball players. **Methods**: A total of 20 healthy young females aged 15 to 17 years old were recruited and were grouped into sedentary control (n=10) and netball player (n=10) groups. The participants were required to walk 6 m down a walkway at a normal gait speed. Spatiotemporal and kinematics data were evaluated using a 3D motion analysis system. A Unipedal Stance Test (UPST) was conducted with eyes open (EO) and eyes closed (EC) for both dominant and non-dominant legs. The average time of the UPST was documented for all of the conditions. Three reaction time tests, including the Human Benchmark Test (HBT), Red-light Green-Light Test (RT), and Ruler Drop Test (RDT), were conducted. **Results**: The netball group showed larger values for body weight, body mass index (BMI), pelvic width, and ankle diameter than the sedentary group. Netball players exhibited a wider stride width compared to the sedentary controls in the spatiotemporal aspect of gait features. The sedentary group showed greater hip internal rotation motion than the netball group. The UPST results showed that sedentary and netball groups showed better standing balance ability for EO compared to EC. For the reaction time test, the netball group had a statistically better reaction time than the sedentary group. **Conclusions**: Findings of this present study indicate that netball players who are physically active exhibited better gait features, balance ability, and faster reaction time compared to sedentary individuals. These findings also imply that netball training can offer beneficial advantages for the young generation to have a better quality of life.
Key Words: Gait, spatiotemporal, kinematic, reaction time, balance ability

Introduction

Awareness and benefits of healthy lifestyles should be cultivated from the early days such as young adults so the changes will become habits in their lifestyles later. The benefits of an active lifestyle for the younger generation should be explored more to increase awareness. It has been reported that research on healthy lifestyles for the youth and also children are still lacking (Hornikova et al., 2019). A study has tried to explore the benefits of netball training to the younger generation because of its growing popularity these days for all ages and gender (Nolte & Hollander, 2020). Limited research was done in assessing the benefits of the netball training to the teenagers, and most of the research were more focused on injury prevention and development programs for the netball athletes. The features selected were related and important to our daily routines which are the gait features, balance ability and reaction time.

Gait can be defined as a pattern or way of walking. Based on some research, a person's health can be reflected by their gait pattern. The abnormality in someone's gait can be related to the neurological, skeletal, or muscular problems they have, which can be observed clearly if the cause is due to weak muscles. Spatiotemporal parameters, including step length, stride length, cadence, speed, and single limb support are commonly measured in the gait analysis. The kinematic and kinetic data describe the locomotion pattern of the human musculoskeletal system (Lencioni et al., 2019). Kinematic analysis represents the position, motion, and trajectories of interest points of the subject to describe the gait pattern without considering the force causing it. For example, kinematics is a method that observes or measures the position of joints and segments of the lower limb through each phase of visual gait analysis. Both kinematic and kinetic properties of the limb and multi-limb behavior analysis are vital in observing and monitoring various sports performances (Hassan et al., 2014, Astone et al., 2019)

Balance is one of the abilities which are paramount for the body and is essential for most human locomotion. According to Brachman et al. (2017), balance is the process of maintaining the position of the body's center of gravity (CoG) vertically over the base of support, which relies on continuous feedback from visual, vestibular, and somatosensory structures to perform smooth and coordinated neuromuscular actions. According to Springer et al. (2007), the timed Unipedal Stance Test (UPST), which is also known as the one leg

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stance test, is the simplest test for measuring static aspects of balance which can be used in diverse settings and requires minimal equipment or training. A previous study which utilized UPST showed that soccer players have a better standing balance compared to the sedentary subjects (Lau et al., 2020). Teunissen et al.(2018) found that a relationship existed between balance performance and basic soccer skills in the youth players. The training and exercise of athletes could help to strengthen their lower limb, thus improving the athlete's standing balance ability. Having good balance is pivotal in the daily routine to discourage injuries from happening (Ng et al., 2018). Balance is also one of the fitness components that is required in sports and other physical activities

Reaction time is the time taken for a subject to respond to a stimulus. A good reaction time is indispensable in daily life as well as in sports. It allows someone to be agile and efficient when responding to stimuli in critical situations, such as driving. A simple reaction time test can determine one's reaction time to a stimulus, e.g., an individual is required to press a button as soon as a light or sound appears (Shelton & Kumar, 2010). The Human Benchmark Test (HBT) and Red Light – Green Light Reaction Test (RT) were used in previous studies for measuring the reaction times of their subjects. A study by Badau et al. (2018) used HBT to calculate the participants' simple motor reactions with their dominant and non-dominant hands. However, the simplest and most commonly used way of evaluating a reaction time is the Ruler Drop Test (RDT). This test is commonly used to assess the reaction time of athletes. RDT is a more economical, simpler, and computer-independent clinical measure. It was previously described and validated for use in children and adolescents (Aranha et al., 2015).

Reaction is the second component of the eye–hand coordination measurement (Paterson, 2010). Eye–hand coordination plays a fundamental role, especially in individual sports that requisites high motor hand skills, such as handball, volleyball, basketball, and racket sports (Menevse, 2011). According to Paul et al. (2011), good eye–hand coordination increases the player's ability to perform complicated movements, respond effectively to external stimuli, and create fluent maneuvers. Jain et al.(2015) found that physically fit subjects naturally had a quicker reaction time. This phenomenon was supported by Ghuntla et al. (2014), who stated that the practice of motor movement, muscular coordination, and speed of movement can improve movement time, thus improving an individual's reaction time. Due to the fact that netball requisites high motor hand skills and is categorized as a fast sport that calls for a fast response, it is appropriate to evaluate the reaction time of a netball player in this study. Comparisons were made between two groups to increase the awareness and benefits of an active lifestyle.

Materials & methods

Participants

This study was approved by the Research Ethics Committee of Universiti Sains Malaysia, and informed consent was obtained from each participant before the test. Twenty healthy volunteers were recruited for the study. The participants included 10 sedentary individuals and 10 state-level netball players with an average age of 16.0 years, ranging from 15 to 18 years of age. The average body mass index (BMI) was 18.34 (±2.57) kg/m^2 for the sedentary group and 21.59 (±2.72) kg/m^2 for the netball group.

Gait analysis

The participants were asked to wear form fitting pants and walk at a normal walking speed on a 6-m walkway. Three sets of data with a full gait cycle were obtained. The spatiotemporal and kinematic data were collected by a 3D motion analysis system using six infrared light cameras. 3D motion data were processed using the Qualisys Track Manager Version 2.7 software. Thirty-five reflecting markers were placed on specific anatomical landmarks on the hip (ASISs and PSISs) as well as on the mid-thigh, knee (epicondyle), mid tibia (shank and malleolus), and foot (second metatarsal and heel) to record the joint motion movement during walking.

Unipedal Stance Test (UPST): Balance ability test

The participants were asked to kick a ball to determine their dominant leg. The UPST was performed on a force platform barefooted under four different conditions, and the test was repeated three times. The standing foot was positioned on the force platform and marked with tape for fixed positioning during the test. Markers were placed on the lower limbs to discern the leg movements during UPST. During data collection, the participants were instructed to stand in a relaxed stance condition on the force platform with their body weight distributed evenly. Then, the participants were requested to stand with their dominant leg without using any assistive devices with their arms crossed over their chests and their non-dominant leg raised at a 90° flexion with eyes open (EO). Data was recorded using a 3D motion analysis system. It detected the markers' movements at the lower limb and recorded movement automatically. The same procedure was applied to the non-dominant leg with EO, and then, the dominant leg with eyes closed (EC). The same steps were then repeated on the non-dominant leg with EC. During the gap between the EO and EC trials, a 3-minute rest interval was given to the participants to prevent fatigue. Each participant needed to perform three trials. The averages of the three trials were recorded and analyzed. The test with EO was stopped by a few conditions, such as when the participants moved their arms from their starting position, when the raised foot touched the floor, when the weight-bearing foot was moved by the participants to maintain balance and when a maximum of 120 s had passed. Another additional condition to stop the test that occurred during the EC was when the participants opened their eyes (Springer et al., 2007).

Reaction Time Test

The Click Reaction Online Test is a test that utilizes an online website to obtain the average reaction time of the participants (Rani et al., 2018). A tablet was used to run this test. Each of the participants used the same tablet to obtain reliable results. The participants were requested to sit comfortably in their seats, and the tabletop and screen were at an appropriate height and distance while the test was conducted. The movement of the subjects' arms were not restricted. Two different click reaction online tests were conducted in this study i.e., a) HBT and b) RT.

The instructions for RT were explained and demonstrated to the participants. They were required to click the large button on the right of the screen to begin the test and waited for the stoplight to turn green. Once the stoplight turns green, the participants must click the large button quickly to get better results and then click on the large button again to continue to the next test. Each participant repeated this test five times continuously; the average reaction times from these five trials were recorded. For the HBT, the participant could click anywhere on the screen or blue box to start the test and wait for the red box to turn green. The participants were required to click as fast as they could to obtain better results once the green box appeared. After the first trial, the box turned blue again, and the participants were required to click on it to start the second trial. The average of five trials of the reaction time test was recorded (Badau et al., 2018).

RDT aimed to calculate the reaction time and hand–eye coordination of the participants. The standardized testing procedure for RDT was used. The participants sat on a chair with the dominant hand or non-dominant hand kept in the mid-prone position, elbow flexed to 90°, and forearm supported on a table with the open hand at the edge of the surface. The ruler was suspended vertically by the researcher so that the 0-cm mark on the ruler coincided with the borders of the fingers. The ruler was then dropped between the thumb and index finger of the participant's hand without prior intimation. The participants were then required to catch the ruler as quickly as possible when it was released. The reading against the dominant index finger lateral border with the ruler was marked for documentation of the distance traveled. The formula: $T=\sqrt{2d/g}$ was used, where d is the distance traveled by the ruler and g is the gravitational constant (Aranha et al., 2015). Two practice trials were given to the participants for familiarization with the test, and three actual trials were conducted; the mean reaction time was then used for the analysis.

Results

All data were analyzed using the Statistical Package for Social Science (SPSS) version 24.0. The Shapiro–Wilk test was used to check the data for normal distribution, while variance homogeneity was investigated using the Levene's test. The Independent T-Test and Mann–Whitney test were used to be compared between the 2 groups. Data are presented as means and standard deviations (mean ± SD) for normally distributed data and median and IQR for skewed data. Statistical significance was accepted at a *p*-value less than 0.05 ($p < 0.05$).

Participants

From the participant data, comparisons between the two groups were made. The results are depicted in Table 1 and Table 2 for demographic and anthropometric data, respectively.

Table 1. Means and standard deviations (SD) of participant demographic data

	Sedentary group (n=10)	Netball group (n=10)	*p*-value
	Mean (±SD)	Mean (±SD)	
Age (years)	16.10 (±0.74)	16.00 (±0.94)	0.795
Weight (kg)	45.35 (±7.75)	55.11 (±8.18)	0.013*
Height (m)	1.57(±0.05)	1.60 (±0.05)	0.200
Body Mass Index (kg/m^2)	18.34 (±2.57)	21.59 (±2.72)	0.013*

* $p < 0.05$

Table 2. Means and standard deviations (SD) of participant anthropometric data

	Sedentary group (n=10)	Netball group (n=10)	*p*-value
	Mean (±SD)	Mean (±SD)	
Leg Length, L_o	0.83(±0.03)	0.83(±0.03)	0.946
Pelvic Width (m)	0.24((±0.02)	0.27(±(0.03)	0.023*
Ankle Diameter	0.21(±0.02)	0.22(±0.01)	0.048*

* $p < 0.05$

Gait Analysis

Spatiotemporal data and kinematics data were analyzed from the gait analysis data based on the walking gait of the participants. Table 3 and Table 4 depict the results from the statistical analysis.

Table 3. Means and standard deviations (SD) for spatiotemporal data

	Sedentary group (n=10)	Netball group (n=10)	*p*-value
	Mean (±SD)	Mean (±SD)	
Speed (ms^{-1})	1.015(±0.700)	1.002(±0.108)	0.751
Stride Width (m)	0.106(±0.218)	0.125(±0.017)	0.043*
Stride Length (m)	1.187(±0.706)	1.163(±0.059)	0.415
Step Length (m)	0.601(±0.391)	0.588(±0.027)	0.415
Actual Cycle Time (s)	1.172(±0.712)	1.172(±0.142)	0.992
Step Time (s)	0.599(±0.038)	0.584(±0.061)	0.528
Stance Time (s)	0.698(±0.046)	0.722(±0.101)	0.511
Swing Time (s)	0.471(0.037)	0.448(±0.041)	0.201
Right Leg Cycle Time	1.169(±0.069)	1.169(±0.132)	0.993
Initial Double Limb	0.122(±0.026)	0.130(±0.012)	0.410
Double Limb Support	0.250(0.041)	0.266(±0.039)	0.376
Cadence (steps/min)	100.74(±6.475)	104.19(±8.877)	0.333
Strides Rate	51.505(±3.085)	52.006(±4.692)	0.781

* $p < 0.05$

Table 4. Results of the independent t-test for kinematics data with their respective anatomical planes

		Sedentary group	Netball group	*p*-value
		Mean (±SD)	Mean(±SD)	
	Sagittal plane			
Pelvis	Max Posterior Tilt (+)	0.173(±4.53)	-1.981(±6.17)	0.385
	Max Anterior Tilt (-)	-5.146(±5.00)	-6.479(±4.35)	0.533
Hip (°)	Max Flexion (+)	26.642(±6.84)	28.726(±5.85)	0.474
	Max Extension (-)	-14.454(±6.94)	-10.638(±3.56)	0.139
Knee	Max Extension (+)	3.336(±2.96)	3.042(±2.02)	0.798
	Max Flexion (-)	-66.501(±6.32)	-67.465(±5.12)	0.712
Ankle	Max Dorsiflexion (+)	17.314(±3.15)	19.105(±2.95)	0.206
	Max Plantarflexion (-)	-18.502(±8.55)	-15.441(±5.48)	0.353
Foot	Max Toes UP (+)	21.398(±4.06)	22.749(±4.05)	0.465
	Max Toes Down (-)	-69.773(±8.40)	-70.089(±7.11)	0.929
	Frontal plane			
Pelvis	Max Left Elevation (+)	6.888(±1.73)	6.163(±1.67)	0.353
	Max Left Demotion (-)	-5.429(±1.94)	-5.238(±2.68)	0.858
Hip (°)	Max Adduction (+)	9.983(±3.61)	9.326(±2.81)	0.655
	Max Abduction (-)	-2.662(±4.44)	-4.850(±2.34)	0.185
Knee	Max Adduction (+)	8.520(±4.66)	8.229(±1.94)	0.857
	Max Abduction (-)	-7.633(±3.39)	-8.701(±2.06)	0.406
Ankle	Max Inversion (+)	14.269(±3.43)	16.143(±2.61)	0.185
	Max Eversion (-)	1.407(±2.06)	1.633(±3.00)	0.846
Foot	Max Instep Up (+)	14.250(±3.41)	16.133(±2.62)	0.183
	Max Instep Down (-)	1.371(±2.24)	1.633(±3.00)	0.827
	Transverse plane			
Pelvis	Max Internal Rotation (+)	6.451(±2.17)	9.090(±3.41)	0.054
	Max External Rotation (-)	-8.513(±3.24)	-8.342(±2.54)	0.897
Hip (°)	Max Internal Rotation	13.377(±6.75)	7.477(±3.84)	0.027*
	Max External Rotation (-	1.752(±8.61)	-4.810(±5.43)	0.056
Knee	Max Internal Rotation	-10.513(±8.66)	-7.897(±4.56)	0.409
	Max External Rotation (-	-30.863(±8.15)	-29.793(±8.27)	0.774
Ankle	Max FF Adduction (+)	19.307(±5.19)	17.607(±7.02)	0.546
	Max FF Abduction (-)	-2.427(±3.35)	-4.083(±5.66)	0.436
Foot	Max Toe-In (+)	0.911(±3.69)	-0.942(±4.51)	0.328
	Max Toe-Out (-)	-21.632(±4.87)	-25.400(±6.25)	0.150

* $p < 0.05$; ° = degree; Max = Maximum

Unipedal Stance Test (UPST): Balance Ability Test

There are two different conditions involved in the UPST, i.e. with eyes open and eyes closed for both dominant and non-dominant legs. The results of UPST are depicted in Table 5 for both groups.

Table 5. Median and IQR of participant UPST data

	Sedentary group (n=10)	Netball group (n=10)	*p*-value
	Median (IQR)	Median (IQR)	
Eyes open (EO) Dominant leg (s)	87.50 (71.30)	116.50 (58.60)	0.217
Eyes closed (EC) Dominant leg (s)	9.75 (15.50)	12.40 (35.50)	0.307
Eyes open (EO) Non-dominant leg (s)	110.30 (82.10)	103.50 (49.20)	0.692
Eyes closed (EC) Non-dominant leg (s)	11.75 (9.70)	23.30 (20.00)	0.082

s = second

Reaction Time Test
Three test results for reaction time, i.e., HBT, RT, and RDT, are depicted in Table 6 for each group.
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Table 6. Median and IQR of participant reaction time data

	Sedentary group (n=10)	Netball group (n=10)	*p*-value
	Median(IQR)	Median(IQR)	
HBT Dominant Hand (s)	0.500(0.065)	0.461(0.550)	0.009*
HBT Non-dominant Hand (s)	0.553(0.080)	0.487(0.034)	0.006*
RT Dominant Hand (s)	0.526(0.087)	0.489(0.040)	0.010*
RT Non-dominant Hand (s)	0.544(0.080)	0.510(0.039)	0.005*
RDT Dominant Hand (s)	0.166(0.067)	0.188(0.012)	0.384
RDT Non-dominant Hand (s)	0.180(0.060)	0.198(0.019)	0.289

* $p < 0.05$; HBT: Human Benchmark Reaction Time Test; RT: Red Light-Green Light Reaction Time Test; RDT: Ruler Drop Test; s: second

Discussion
Table 1 depicts the participants' demographic data; there were no significant differences between groups for the age and height of the subjects with the exception of weight (*p*=0.013) and BMI (*p*=0.013) between the sedentary and netball groups. Based on the results shown in Table 2 for the anthropometric data, the pelvic width and ankle diameter mean values were significantly higher in the netball group than in the sedentary group. Although the body height did not show any significant difference between the groups, the netball group (1.60 m) showed a higher mean value for height compared to the sedentary group (1.57 m). Body height is a crucial factor in sports performance especially in the netball game. Thomas et al. (2019) stated that netball squads are relatively heterogeneous in physical stature, whereby body height is routinely accepted as a selection criteria for defenders and shooters in netball. The results of this study showed that the netball players were significantly heavier than the sedentary group. Heavier weight and a big build of the physical body is one of the characteristics that are beneficial in netball players. For example, a tall and heavy goalkeeper can block the opponents and remain stable more efficiently even after being pushed compared to a shorter and lighter goalkeeper. The significant difference in pelvic width observed in this study may be related to the significant difference in the participants' body weights. The main function of the pelvis is weight bearing of the upper body and transfer of that weight from the axial skeleton to the appendicular skeleton. Thus, the netball players may have had a bigger pelvic width due to their heavier weight compared to the sedentary group with their lighter weight. It is assumed that an increase in body weight will also increase pelvic width.

Based on Table 3 for gait analysis, the spatiotemporal data showed no significant differences between groups, with exception of stride width (*p*=0.043). Stride width is the difference in mediolateral axis between right and left heel markers (Brindle et al., 2014). This result may be due to the differences in the mean value of pelvic width between the two groups. There are limited previous studies that state the relationship of the pelvic width with step width. According to the normal step width varies with age; thus, it is appropriate to normalize it by dividing it by the pelvic width. The pelvic width may have affected the step width of the sedentary and netball groups.

Table 4 shows the results for kinematics data; there were no significant differences between the groups for each segment at the frontal and sagittal plane, except that there was a statistically significant difference at the transverse plane for the hip motion, which is maximal internal rotation (*p*=0.027). Hip joint internal rotation occurs when the femur rotates within the hip joint towards the midline of the body. It also occurs during standing when the lower limb is fixed and the pelvis rotates (Richards, 2008). It was found that the mean value for the maximum angle of hip internal rotation for the sedentary group was statistically higher than that of the netball group. This observation reveals that the hip motion of the sedentary group was more internally rotated than that of the netball group. According to Shore et al. (2018), the hip rotation value was lower in children with a high BMI than in those with a low BMI. Additionally, Kouyoumdjian et al. (2012) reported that the range of hip rotation decreases with age and is lower in men and subjects which are overweight. Hence, their overweight subjects had a lower range of hip rotation, which might support the findings of this study where the participants in the netball group were heavier in weight and had a higher BMI in contrast to those in the sedentary group. Simoneau et al. (1998) reported that the difference in hip rotation range of motion by measurement position is influenced by not only ligaments around the hip joint but also by the joint capsule and muscle tendons. It can be surmised that the netball group's lower internal hip rotation may be caused by more toned muscles due to training, which needs to be confirmed in further studies.

Based on Table 5 showing the results of the balance ability test, there were no significant differences between groups when the data of UPST measured under all conditions were compared. Thus, it can be presumed that the functional and capability of the participants' lower leg muscles were still in good condition for both groups to complete the UPST with eyes open and closed using the dominant and non-dominant legs for 120 seconds. According to Novak (2016), muscle strength has been reported to reach a peak value between 25 to 35 years of age, is maintained or is slightly lower between 40 and 49 years of age, and then is ~12–14% less a decade after 50 years of age. Additionally, the level of the participants in the netball group may have been related to their UPST results. The netball participants were only at the state level but not national level and were of a young age. Most of them were amateur players and not professional players. According to the previous study, the balance ability and stability of the athletes are different based on the level of their playing experience.

Table 5 shows that both the sedentary and netball groups exhibited better times under the EO condition than under the EC condition. Based on the mean value, netball players recorded a better balancing time during UPST under the EC condition. This result implied that the sedentary group might have a stronger visual dependence to keep up their postural performance. This is supported by Paillard et al. (2006), who stated that intense training allows professional soccer players to become less dependent on vision in controlling their posture such that vision can be used to orchestrate the emanated information from the game.

Results of the UPST of the non-dominant legs with EO showed that the sedentary group was more balanced in contrast to the netball group. However, the netball group showed that their dominant leg was more balanced and had the longest time during the UPST with EO. This may be due to the nature of a netball player that will use their dominant leg in most parts of the game and training such as for one foot landing and jumping, and these situations are anticipated to strengthen the dominant leg of netball players. Hopper et al. (1992) found that movements in the netball and footfall landing pattern are mostly on the dominant sides of the players.

Table 6 shows the comparison results using the Mann–Whitney test for the reaction time test. The HBT, RT, and RDT for both dominant and non-dominant hands are exhibited in Table 6. When comparing the results of HBT and RT between the groups, some differences were present. Both of these tests illustrated that the participants in the netball group were active and had faster reaction time for both dominant (HBT: p=0.009; RT: p=0.010) and non-dominant hands (HBT: p=0.006; RT: p=0.005) in contrast to the sedentary group. This could be attributed to the continuous and consistent training and practice of the netball players. It can also be speculated that the netball players have better visual reaction times that may refine their hand–eye coordination performance. According to Gavkare et al. (2013), the speed among athletes compared with non-athletes indicates enhancement in their concentration and alertness, better muscular coordination, and upgrade performance in terms of speed. This result of a faster reaction time of those in the netball group is also supported by the study by Kuan et al. (2018), who determined that greater involvement in sports activities enhances an individual's eye–hand reaction time and anticipation responses. This may contribute to the capability of netball players, especially the defenders, to predict the direction of a pass to catch or to intercept the ball.

In this study, RDT showed no significant difference when comparing the dominant and non-dominant hands of both groups. The test may be less strict because it does not involve electronic timing, and in one reliability study of the physical test, it was considered moderate when compared to the electronic tests (Aranha et al., 2015).

Conclusions

The results suggested that netball players have a significantly wider stride width and lower hip internal rotation due to their heavier weight in contrast to that of the sedentary group. For balance ability, the state level netball players showed a better standing balance ability when compared to the sedentary group. The dominant leg of the netball players showed superior results contrasting to the non-dominant legs. This can be due to the preferred leg during jumping, single leg landing in training, and game sessions of the netball players. Nevertheless, the non-dominant legs for the sedentary groups exhibited better results compared to their dominant legs. Perhaps the non-dominant leg takes the full weight of the body weight during daily tasks, such as kicking, that predominantly uses the dominant leg. UPST is one of the simplest but most useful tests in the measurement of static balance ability for comparing different groups in the population and healthy people.

According to the reaction time test results, the female state-level netball players had a better reaction time in contrast to the sedentary group. Participation in sports influenced their ability to react faster to a certain stimulus. It enhances hand movement, resulting in achieving a faster time in the HBT and RT test, as shown in the results. Therefore, the reaction time was affected by physical activity for the netball group. This may be due to the improvements in the eye–hand reaction time and visuospatial intelligence upon taking part in sports activities, as proposed by a previous study (Akarsu et al., 2009). Based on these results, the advantages of physical activities are observable in the teenage age group, as it enhanced the reaction time in this study.

Conflicts of interest - There were no conflicts of interest in this study.

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