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Full Length Research Paper

Relationships between perceptual-motor skills and postural balance in nine years old boys

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The aim of this study is to investigate relationship between static-dynamic balance performance and two-hand coordination, reaction time, anthropometric measurements and leg strength. Fifty voluntary male children (age: 9.29 ± 1.11 years, height: 138.86 ± 7.86 cm, weight: 35.20 ± 9.2 kg) who did not exercise regularly were included into the study. The correlation Static Balance (SB) and dynamic balance (DB), with leg strength (LG), vertical jump (VJ), reaction time (RT), two-arm coordination and anthropometric measurements were investigated. As a result, although, no correlation was found between balance parameters and reaction time (p>0.05), higher correlation was found between balance parameters and two-hand coordination, strength and some anthropometric parameters (p<0.05) in nine-year old male children. Furthermore, it is suggested that in order to develop static and dynamic balance in children, sport education programs should not only include the gross-motor coordination skills, but also include manipulative and fine motor coordination skills. These findings may be useful for trainer and physical education teachers while preparing sport education programs.

Key words: Postural control, children, muscle strength, coordination, anthropometry.

INTRODUCTION

The functions of the postural control can be grouped as postural orientation and postural equilibrium. Postural orientation is the active motor control of body alignment and tone in regard to gravity, support surface, visual environment and internal references (Horak, 2006). Postural control develops through three distinct processes in childhood: (1) a sensory organizational process, in which one or more of the orientation systems (visual, somatosensory and vestibular) are integrated within the Central Nervous System (CNS) (Steindl et al., 2006), (2) a motor adjustment process, resulting in coordinated and properly scaled sensorimotor responses (Assaiante et al., 2005) and (3) an internal representation of body scheme that slowly matures during childhood (Schmitz and Assaiante, 2002; Roncesvalles et al., 2005). The development of these three sensory systems takes place at different degrees in children (Woollacott and Shumway-Cook, 1994).

In the sense of the development of the somatosensory systems, there are contradictory results in literature. Some studies have demonstrated that the somotosensory function is matured through the ages of 9 to 12 (Riach and Hayes, 1987; Cherng and Chen, 2001) whereas other studies have reported that maturation of the somatosensory system occurs much earlier such as the ages of 3 to 4 year old (Hirabayashi and Iwasaki, 1995; Sparto et al., 2006). Nevertheless, most of the studies have also reported that visual cues play a prominent role on stability (balance), locomotors (walking, running) and manipulative (hitting the ball with racket) skills of children that are 7 to 15 years old (Shumway-Cook and Woollacott, 1985; Sparto et al., 2006). All of these skills are called gross motor skills in motor development studies.

On the other hand, in order to achieve some actions such as eating, dressing, drawing, the CNS should reach a certain degree of maturity (Udennann et al., 2004). The acquisition of the fine motor skills such as two-hand coordination and reaction time is also established by means of the vision afferent system like the acquisition of gross motor skills. In addition, this ability enables the sensory organizational process to form appropriate muscular synergies. The exact nature of those mechanisms in terms of the development of fine motor skills has not been studied yet comprehensively.

The everyday activities require that children master different motor skills. Motor competence has important implications for different aspects of development in children and adolescents. For example, there is now increased awareness that children with low motor competence are at risk of a variety of psychological difficulties and health related fitness. Cardiorespiratory endurance, muscular strength and endurance, body composition and flexibility are often referred to as health-related fitness and are usually associated with disease prevention and health promotion (Haga, 2008).

However, to our knowledge, there is little study concerning the comparison of the balance parameters with two-hand coordination and reaction time in children (Hatzataki et al., 2002). On the other hand, it was reported that the studies more generally focused on postural control development and CNS maturation in children (Sparto et al., 2006; Bair et al., 2007; Riach and Hayes, 1987). At the same time, researches in literature have been observed between motor comparence and fitness of children (Haga, 2008; Wrotniak et al., 2006).

The aim of this study is to investigate the relationships between static and dynamic balance performance with two-hand coordination, the reaction time, anthropometric measurements and leg strength. The fact that the duration of maintaining of the static and dynamic balances of the children with better two-hand coordination and reaction time will be higher is hypothesized in this study.

MATERIALS AND METHODS

Participants

Fifty voluntary male children (age: 9.29 ± 1.11 years, height: 138.86 ± 7.86 cm, weight: 35.20 ± 9.2 kg) who did not exercise regularly were included in to the study. The parents of children were notified by a letter and they were asked for the participation of their children in the reliability assessment for tests. They gave their informed consent for the experimental procedure as required by the WMO (1966) declaration. Male children who had no neurological disorders, vestibular-visual disorder, lower-extremity injury and orthopedic problem and who had not attended regularly to any sport activity previously were included into study group. This study was conducted in the Biomechanics Laboratory of the School of Physical Education and Sports of Marmara University. The study was approved by the local ethical committee of Marmara University in İstanbul.

Procedure

The participants were taken into the laboratory one time for the tests. Prior to testing, participants were familiarized with the balance instrument and practice sessions were applied on the testing procedures to decrease the change of a learning effect occurring during testing. The tests were performed in the same hours of the days (10 AM to 1 PM) when their bodies were rested and the necessary precautions were applied to prevent the influence of the environmental factors such as noise and temperature. The measurements were achieved for 20 min for each child. Tests for the whole group were completed five days later. First, the heights, legs height of the participants were measured by means of portable stadiometer (Holtain Ltd, Pembrokeshire, UK.), the foot-length and the foot-width were measured by sliding caliper (Clas Ohlson, Sweden) and the weights of the participants were measured by an electronic scale (Seca 770 Wedderburn, GmbH, Germany) without having clothes (light clothing with a weight of approximately 0.1 kg). Then, motor and balance tests were performed (Tables 1 and 2).

Two-arm coordination was measured by using the instrument called Lafayette (model 32532, IN USA). The participants were placed in front of the table where the instrument is located and, they were sat on a chair in a fashion that their hands would be in ergonomic position. The height of the chair was fixed according to the sitting height of the participants and to the height of the participant. First the instrument was introduced to the participants and then, one trial occasion was given to them. The participants were required to begin the test with the “start” command, the duration was initiated and it was terminated when it was reached to the end point. The number of errors and the time parameters (sn) were assessed by performing the test in clockwise and counter clockwise directions. The measurements were repeated twice and the best results of two measurements were assessed (Pennathur et al., 2003).

For the measurements of reaction time, choice reaction times were measured by using the instrument called Lafayette (model 54035A, IN USA). The participants were asked to stop the time by pushing to the button with same color as the visual stimulus when the light stimulus with either red or green color was applied. The test was repeated five times and the best time was assessed as milliseconds (ms). For the strength, leg dynamometer (back and leg dynamometer, Takai, Tokyo, Japan) was used in the measurement of leg strength (LS). After the warm-up exercises performed for 5 min, subjects put their feet on the dynamometer stand in a fashion that their knees was in 135° flexion, they pulled the vertical bar of dynamometer which they grasped with their hands while their arms were stretched, their backs were up-right and their trunks were slightly bent forward by using their feet in maximum ratios. The maximum value (kg) was recorded by repeating three times this pulling action.

Vertical jump measurements were taken by performing squat jump with double legs (SJB), squat jump with right leg (SJR) and squat jump with left leg (SJL) (Newtest, Oulu, Finland). Before the test, the participants were asked to perform a trial jump. In SJ, the knee-hip angles of the subjects were ensured to be 135 degrees by measuring by goniometer. At the beginning of the test, the subjects were asked to jump as higher as possible by putting their hands to their waist. Every athlete jump three times (the rest duration 1 min) and the highest record (cm) were used to analyze of jumping performance.

For studying the balance, static and dynamic balance measurements were done by using Prokin 5.0 (Pk-Manop-05-en-01 Bergomo, Italy). After explaining the tests to the participants, data entry (height, weight, age) and the calibration of the instrument were made. The feet of the subjects were placed on the balance platform nakedly (in a fashion that the distance between feet was 10 cm and the projection of the maximum point of the medial arcs was on the x-axis). Afterwards, the participants were asked to hold themselves fixed in (0) point by looking to the screen in front of them in fashion that their hands were placed on the waist. At the end of each test, the subject was requested to rest (the rest duration 2 to 4 min) while the instrument was being calibrated again. No verbal feedback was given to the subject during the measurements except the necessary cases (http://www.tecnobody.it). Static balance tests (with 30-s time);

a) Bilateral stance: it was performed as either eyes open (EO) or eyes closed (EC). The obtained data were assessed in terms of eyes open perimeter (EOP), eyes open ellipse area (EOE), eyes closed perimeter (ECP), eyes closed ellipse area (ECE), Romberg test perimeter ratio (RTPR) and Romberg test area ratio (RTAR). In case of a sequence, the software will calculate the Romberg test in two variables: perimeter ratio between closed eyes and opened

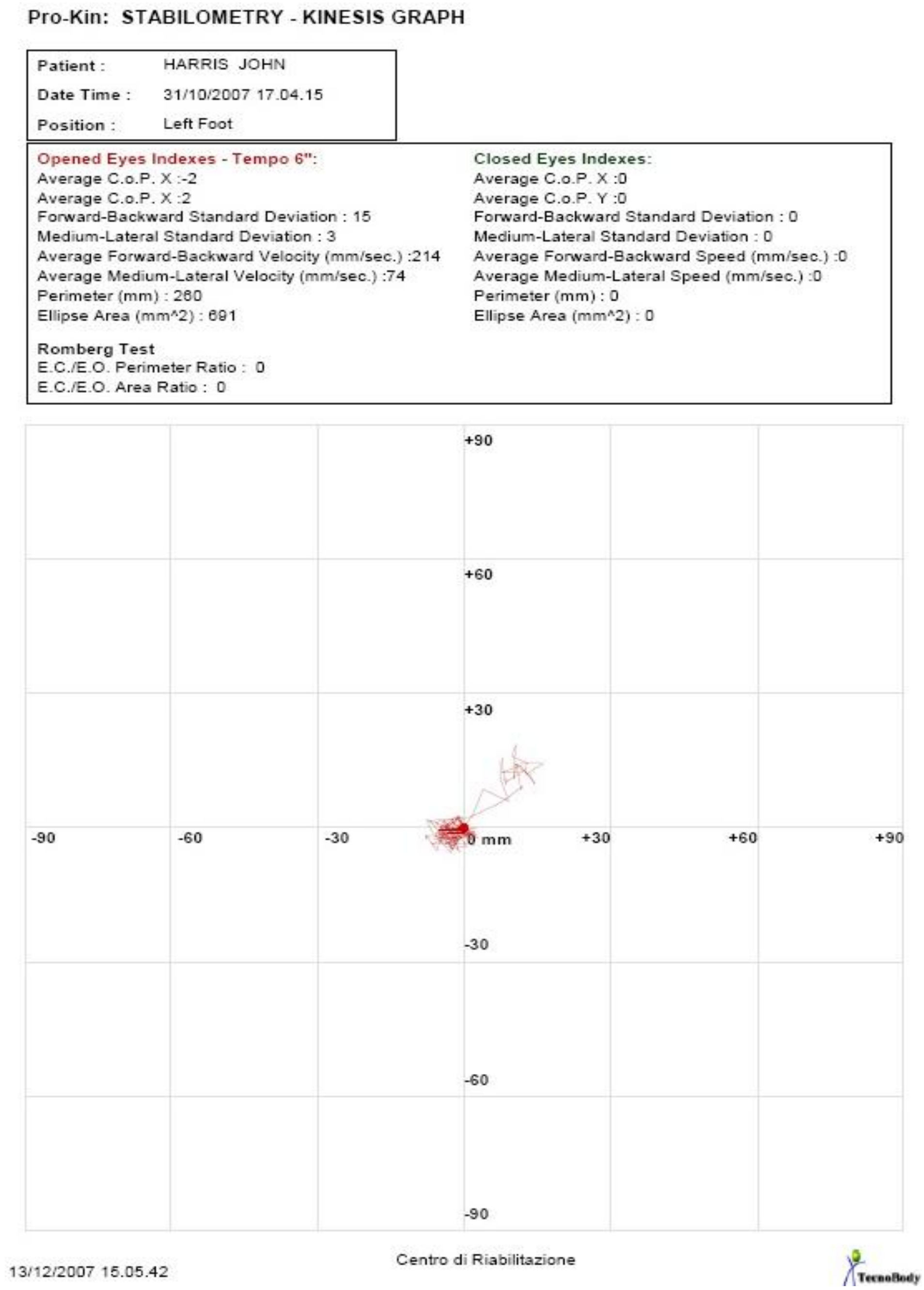

Figure 1. Static balance tests.

eyes and area ratio between closed eyes and opened eyes (Figure 1).
b) Unilateral stance: static balance was measured on right and left leg respectively while the eyes were open and right foot perimeter (RFP), right foot ellipse area (RFE), left foot perimeter (LFP) and left foot ellipse area (LFE) values were taken.

Dynamic balance test (equilibrium/disequilibrium test): in this test, the participant saw some galleries that come against. The participants' scope was to enter into those galleries and to maintain the tilting board as firm as possible. In this test, medio-lateral direction was used. The test was applied for 60 s. Front/right standard deviation, backward/left standard deviation and distance medium error parameters were assessed (Figure 2).

Statistical analysis

The relationship between balance parameters and leg strength, anthropometric measurements, vertical jump, reaction time and two-arm coordination were investigated by using multiple correlations. The level of statistical significance was set to $p \leq 0.05$. The data analysis was performed through SPSS for Windows 14.0 (SPSS Inc, Chicago, IL, USA).

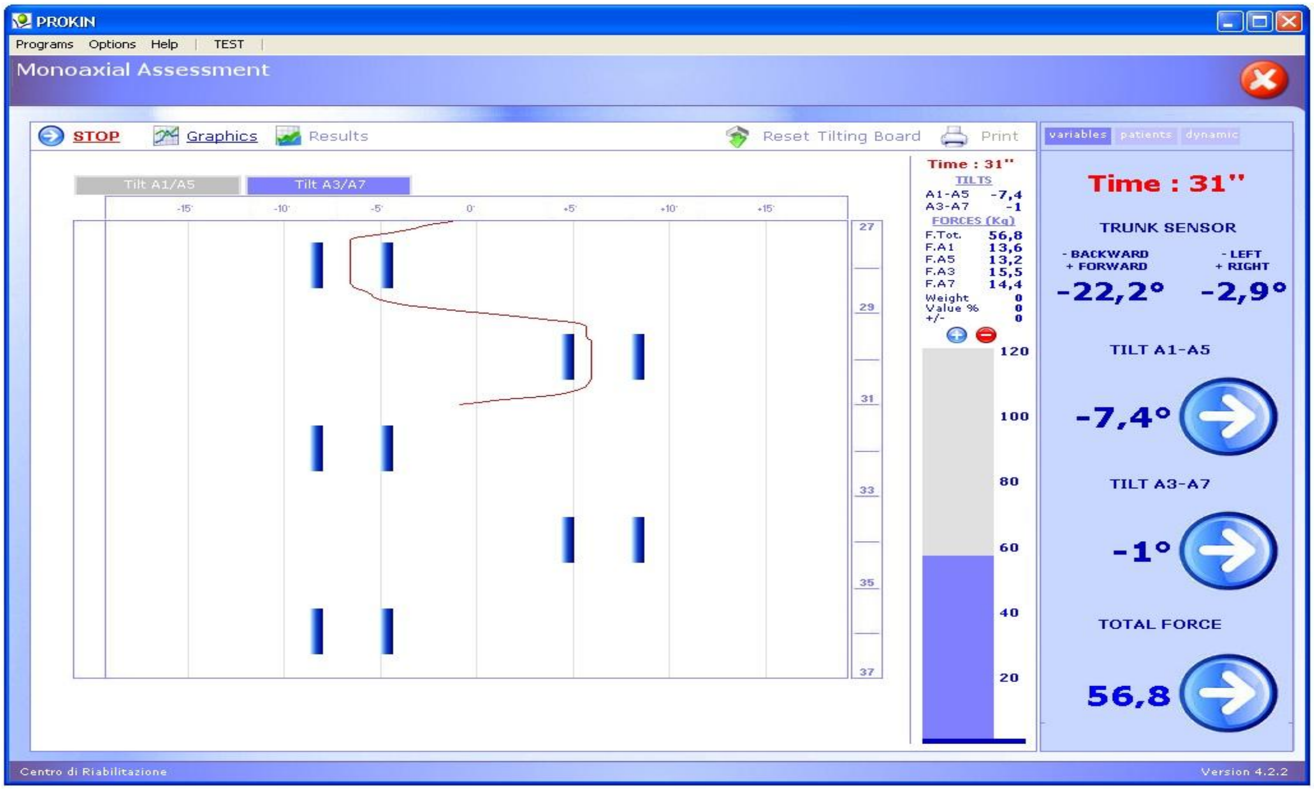

Figure 2. Dynamic balance test (equilibrium/disequilibrium test).

RESULTS

All data are presented as mean ± standard deviation (Tables 1 and 2). The correlations between the balance parameters and the anthropometric measurements were shown in Table 3. There is higher negative correlation between unilateral stance perimeter (RF) with height (r = -0.311 p<0.028) and foot length (r = -0.301 p<0.034) and, unilateral stance ellipse area (RF) and foot length (r = -0.279 p<0.049). There is a strong correlation between bilateral stance EC ellipse area and leg length (r = -0.343 p<0.015).

Two-hand coordination and choice reaction time measurements were given in Table 4 comparatively with balance parameters. A positive correlation was found between the number of errors in two-hand coordination test in clockwise direction and bilateral stance EO ellipse area (r = 0.374 p<0.007), EC ellipse area (r = 0.334 p<0.018), unilateral stance (RF) perimeter (r = 0.344 p<0.014), ellipse area (r = 0.306 p<0.031), unilateral stance (LF) ellipse area (r = 0.340 p<0.016). There are higher positive correlations between the time of two-hand coordination test in clockwise direction and bilateral stance EO perimeter (r = 0.316 p<0.026).

There are higher positive correlations between the number of errors of two-hand coordination test in counter clockwise direction and bilateral stance EC perimeter (r = 0.305 p<0.031), EC ellipse area (r = 0.350 p<0.013), unilateral stance (RF) perimeter (r = 0.483 p<0.00), ellipse area (r = 0.363 p<0.009), unilateral stance (LF) perimeter (r = 0.408 p<0.003), ellipse area values (r = 0.352 p<0.012). There are higher correlations between the number of errors of two-hand coordination test in clockwise direction and dynamic balance front/right standard deviation (r = 0.501 p<0.000), backward/left standard deviation values (r = 0.383 p<0.006). There is no correlation between the number of errors of two-hand coordination test in counter clockwise direction and dynamic balance front/right standard deviation (r = 0.291 p<0.040), backward/left standard deviation values (r = 0.346 p<0.014). There is no correlation between the choice reaction time and balance parameters (SB, DB) values.

In Table 5, when the relationship between the balance parameters and the leg strength was investigated. There are negative correlations between the leg strength and unilateral stance perimeter (RF) (r = -0.053 p<0.012), perimeter (LF) (r = -0.317 p<0.025), ellipse area values (r = -0.329 p<0.020). There is negative correlation between the squat jump and bilateral stance EO ellipse area (r = -0.319 p<0.024), unilateral stance perimeter (RF) (r = -0.321 p<0.023), ellipse area values (r = -0.328 p<0.020). There is a strong positive correlation between jump with right leg and bilateral stance Romberg test area ratio values (r = 0.302 p<0.033). However, the correlation between dynamic balance and other jump, leg strength

Table 1. Descriptive statistics for antropometric measurements, two-arm coordination, VJ, LS and RT.

Variable		Mean Std. deviation
Antropometric measurements	Foot length (cm)	21.90±1.58
	Foot width (cm)	8,28±0.70
	Leg height (cm)	67±5.19
Two-arm coordination	Clockwise error	7.88±5.66
	Clockwise (sn)	40.43±13.67
	Counter Clockwise error	7.94±5.25
	Counter Clockwise (sn)	38,65±9.60
Jump	Squat jump (cm)	22.00±4.52
	Right foot (cm)	10.92±2.64
	Left foot (cm)	11,28±2.45
Leg strength	Leg strength (kg)	62,85±15.06
Reaction time	RT (ms)	451±95.39

Table 2. Descriptive statistics for balance test scores.

Variable		Mean Std. deviation
Dynamic balance (M/L)	Front/right Sd.	1.16±0.72
	Backward/left SD.	1.26±0.65
	Distance medium error (%)	0.20±0.33
Static balance	EO perimeter (mm)	696.22±213.20
	EO elipse area (mm^2)	800.70±567.42
	EC perimeter (mm)	798.80±296.24
	EC elipse area (mm^2)	990.14±1392.26
	Romberg test perimeter ratio	121.66±35.61
	Romberg test area ratio	148.54±115.47
Right foot static balance	Perimeter (mm)	1765.24±477.43
	Elipse area (mm^2)	1757.28±948.82
Left foot static balance	Perimeter (mm)	1801.08±578.71
	Elipse area (mm^2)	1707.83±934.96

parameters were not significant.

DISCUSSION

This research was conducted with nine-year old male children in order to investigate whether there is a positive relationship between the postural balance parameters and two-hand coordination, reaction time and leg strength. The main finding this study even though there was no correlation between the balance parameter (SB-DB) and choice reaction time ($p>0.05$), there was a significant positive correlation between the two-hand coordination and balance, strength, vertical jump and some anthropometric parameters ($p<0.05$) in nine-year old male children.

These results show that there is a correlation in the positive direction with two-hand coordination while eyes are open and eyes are closed as well as a correlation between bilateral and unilateral static balance (RF-LF) in the positive direction while eyes are open. In addition, a correlation has been found in the positive direction between two-hand coordination and dynamic balance (medio-lateral direction) parameters. These results show

Table 3. The correlation of the anthropometric measurements and balance parameters and the significance level.

Variable	Height (cm)		Weight (kg)		Foot length (cm)		Foot width (cm)		Leg height (cm)	
	r	P	r	p	r	p	R	P	r	P
DB front/right standard dev.	-0.262	0.066	-0.137	0.344	-0.248	0.083	-0.193	0.180	0.053	0.714
DB backward/left standard dev.	0.117	0.41	0.212	0.140	0.0252	0.077	0.239	0.095	-0.103	0.477
DB distance medium error (%)	-0.082	0.571	0.044	0.763	-0.005	0.974	-0.003	0.984	0.201	0.161
EO perimeter (mm)	-0.13	0.34	-0.072	0.617	-0.042	0.771	-0.057	0.695	0.027	0.852
EO ellipse area(mm^2)	-0.07	0.631	0.032	0.827	0.071	0.625	0.067	0.643	-0.054	0.709
EC perimeter (mm)	-0.15	0.298	-0.242	0.091	-0.274	0.054	-0.070	0.630	-0.190	0.186
EC ellipse area (mm^2)	-0.08	0.550	-0.145	0.314	-0.137	0.344	0.000	0.998	-0.343*	0.015
Romberg test perimeter ratio	-0.07	0.597	-0.173	0.229	-0.208	0.147	-0.032	0.827	-0.110	0.446
Romberg test area ratio	0.014	0.923	-0.100	0.491	-0.145	0.316	0.071	0.626	-0.070	0.627
RF perimeter (mm)	-0.311*	0.028	-0.207	0.150	-0.301*	0.034	-0.180	0.212	0.072	0.620
RP ellipse area (mm^2)	-0.253	0.076	-0.170	0.237	-0.279*	0.049	-0.033	0.823	0.052	0.720
LF perimeter (mm)	-0.247	0.084	-0.137	0.344	-0.224	0.117	-0.186	0.195	0.256	0.073
LF ellipse area (mm^2)	-0.254	0.076	-0.145	0.316	-0.229	0.110	-0.077	0.593	0.160	0.267

*$p \le 0.001$, ** $p \le 0.05$.

Table 4. The correlation of the two-hand coordination, reaction time and balance parameters and the significance level.

Variable	Clockwise (error)		Clockwise (sn)		Counter clockwise error		Counter clockwise (sn)		Reaction time (ms)	
	r	p	r	p	r	P	R	p	R	P
DB front/right standard dev.	0.501**	0.000	-0.032	0.824	0.291*	0.040	0.131	0.364	0.066	0.647
DB backward/left standard dev.	0.383**	0.006	-0.258	0.079	0.346*	0.014	-0.026	0.860	-0.165	0.252
DB distance medium error (%)	0.178	0.217	0.115	0.427	0.197	0.168	0.055	0.705	0.012	0.936
EO perimeter (mm)	0.126	0.383	0.316*	0.025	0.237	0.096	0.187	0.194	-0.064	0.658
EO ellipse area (mm^2)	0.374**	0.007	0.126	0.382	0.218	0.127	0.071	0.624	-0.008	0.956
EC perimeter (mm)	0.175	0.225	0.274	0.054	0.305*	0.031	0.140	0.332	0.064	0.661
ECE ellipse area (mm^2)	0.334*	0.018	0.166	0.249	0.350*	0.013	0.000	0.997	-0.073	0.615
Romberg test perimeter ratio	0.015	0.918	0.092	0.525	0.062	0.665	0.106	0.462	-0.058	0.689
Romberg test area ratio	0.089	0.540	0.095	0.511	0.223	0.119	0.045	0.775	-0.109	0.451
RF perimeter (mm)	0.344*	0.014	0.255	0.074	0.483**	0.000	0.058	0.689	0.176	0.222
RF ellipse area (mm^2)	0.306*	0.031	0.254	0.074	0.363**	0.009	0.146	0.310	0.154	0.286
LF perimeter (mm)	0.219	0.127	0.220	0.124	0.408**	0.003	0.108	0.457	-0.065	0.651
LF ellipse area (mm^2)	0.340*	0.016	0.219	0.126	0.352*	0.012	0.172	0.232	-0.082	0.572

*$p \le 0.001$, ** $p \le 0.05$.

Table 5. The correlation of the VJ, LS and balance parameters and the significance level.

Variable	Leg strength (kg)		Vertical jump (cm)		Jump right (cm)		Jump left (cm)	
	r	p	r	p	r	p	R	P
DB front/right standard dev.	-0.126	0.385	-0.065	0.652	0.109	0.453	0.092	0.526
DB backward/left standard dev.	0.092	0.526	-0.159	0.270	-0.079	0.584	-0.066	0.647
DB distance medium error (%)	-0.025	0.861	-0.165	0.253	-0.007	0.962	-0.043	0.768
EO perimeter (mm)	-0.240	0.094	-0.220	0.125	-0.063	0.663	0.003	0.986
EO ellipse area (mm^2)	-0.193	0.180	-0.319*	0.024	-0.183	0.203	-0.117	0.420
EC perimeter (mm)	-0.095	0.510	0.082	0.571	0.222	0.121	0.225	0.116
ECE Ellipse area (mm^2)	-0.100	0.489	-0.015	0.916	0.046	0.750	0.080	0.583
Romberg test perimeter ratio	-0.006	0.969	0.210	0.144	0.256	0.073	0.206	0.152
Romberg test area ratio	0.024	0.868	0.193	0.180	0.302*	0.033	0.264	0.064
RF perimeter (mm)	-0.353*	0.012	-0.321*	0.023	-0.097	0.504	-0.099	0.493
RF ellipse area (mm^2)	-0.262	0.066	-0.328*	0.020	-0.010	0.945	-0.181	0.209
LF perimeter (mm)	-0.317*	0.025	-0.216	0.131	-0.112	0.438	0.007	0.960
LF ellipse area (mm^2)	-0.329*	0.020	-0.276	0.052	-0.112	0.400	0.022	0.881

*$p \leq 0.001$, **$p \leq 0.05$.

that the children having good two-hand coordination have also good static and dynamic balances.

The ability to balance and two-hand coordination is associated with increasing accuracy and consistency of eye movement, which is acquired with age. The relative contribution of peripheral vision in equilibrium control increases from 8 to 9 years of age to adulthood. In addition, an increasing body of evidence suggests that information processed through vision, particularly from peripheral visual cues providing exteroceptive information about the environment, is the most reliable source of perceptual information for balance control, especially in children. Indeed, the anatomical damping and the segmental stabilizations improved in subjects from 5 to 15 years when visual cues were available (Hatzataki et al., 2002; Cumberworth et al., 2007; Mallau et al., 2010). On the basis of visual perceptual studies, it may be speculated that this study's groups of subjects from 9 to 10 years were still presumably dependent on visual cues. As such, the correlation found between the balance and two-hand coordination in the children can be explained accordingly.

On the other hand, research has shown significant positive associations among motor skills, visual-motor coordination, gross motor development, and self-reported athletic coordination and physical activity in youth (Wrotniak et al., 2006). Gross motor skills involve larger movements and make use of the arms, legs, feet or the entire body balance. Fine motor skills involve smaller, more intricate movements and make use of the hands, fingers, wrists, tongue, lips and toes. Gross motor skills and fine motor skills often develop together and various gross motor skills can enhance fine motor skills (Pinar and Erkut, 2001).

In this research, it is speculated that the positive correlation between two-hand coordination and static dynamic balance parameters can result from the simultaneous development of gross-motor skills and fine motor skills development and they support one another.

Hatzataki et al. (2002) has researched the balance parameters, perceptual, cognitive and motor skills, as well as the correlations between the static and dynamic balance. They found a positive correlation between static balance parameters and some visio-motor tests, reaction time and depth perception tests. However, as stated in our research, they were not able to find a correlation between choice reaction time and balance parameters (Hatzataki et al., 2002). Arslanoğlu et al. (2010) were not able to find a statistical correlation between the reaction time and balance parameters in badminton players. The findings in those researches are in consistence with our findings. Debrabant et al. (2012) researched the reaction time correlation between the ages and gender in children during their research, and they found that the reaction time reach the maximum speed in 9 to 10 year-olds. The reaction time is required in order to be able to respond to different situations, which cannot be anticipated, fast and immediately (Pinar and Erkut, 2001). For the fact that no correlation between static-dynamic balance parameters and choice reaction time has been found, could be because the reaction time requires more swiftness ability than the balance ability.

The research conducted reveals that the motor competence and physical fitness are correlated (Haga, 2008; Wrotniak et al., 2006). Haga (2008) applied the movement assessment battery for children (MABC) test in order to measure the motor competence, and TPT tests in order to measure the physical fitness in children and he found a significant correlation between the balance and manual dexterity (motor competence) and between balance and physical fitness parameters in male children. Also, in this research, a high negative correlation was found between static and balance parameters and leg strength parameters.

As the strength increases, it has been concluded that the static and dynamic balance parameters become also much better. Heitkamp et al. (2001), in his research reported that postural control is associated with lower extremity muscle strength and Matton et al. (2007) and Kambas et al. (2004) reported in their research that as the strength increases, the balance also increases and the decrements become lower. The findings of these researches support our findings.

A higher negative correlation was found between the static and dynamic balance parameters, foot and leg length and height. In other words, as the leg length and height increase, static EC bilateral stance and unilateral stance are impaired. In preadolescent children, the growth of the body parts are faster (Malina et al., 2004) and this situation influences the balance unfavorably. The falling and the injury ratios might be higher during this period. Parents, teachers and trainers should be careful and they should take the necessary precautions.

Conclusions

As a result, in this study, although no correlation was found between balance parameters and reaction time ($p>0.05$), higher correlation was found between balance parameters and two-hand coordination, strength and some anthropometric parameters ($p<0.05$) in nine-year old male children. Furthermore, it is suggested that in order to development static and dynamic balance in children, sport education programs should not only include the gross-motor coordination skills, but also include manipulative and fine motor coordination skills. These findings may be useful for trainer and physical education teachers while preparing sport education programs.

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