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Investigation of Factors Affecting Motor Competence in Healthy Early Adolescents

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ABSTRACT
Objective: This study aims to retrospectively evaluate the fundamental motor competence of healthy early adolescents and to investigate the affecting factors. **Materials and Methods:** 89 children aged 11.33±0.95 were included in the study. Minnesota Manual Dexterity Test (MMDT) for manual dexterity, 9-Hole Peg Test (9-HPT) for finger dexterity, Korebalance™ Premiere for balance, manual muscle strength measurement device for quadriceps muscle strength, hand dynamometer for hand grip strength, EMG Biofeedback for muscle activation was used. **Results:** Compared by gender, there was a statistically significant difference in the right and left-hand placing of MMDT and 9-HPT (p=0.004, p=0.041, p=0.004, respectively). In comparison of the age groups, there was a statistically significant difference in the left-hand placing and turning subtests of MMDT and left grip strength (p=0.010, p=0.048, p=0.025, respectively). In a correlation analyses, age had a correlation with the left-hand placing of MMDT (r=-0.336, p=0.001); and left grip strength (r=0.219, p=0.039). Height and weight had a correlation with dynamic balance (r=-0.242, p=0.022; r=-0.244, p=0.021). Weight and BMI had a correlation with static balance (r=0.342, p=0.001; r=0.305, p=0.004) and EMG Biofeedback score (r=0.237,p=0.025; r=0.212,p=0.046). **Conclusion:** Manual dexterity and hand grip strength develop with age in children, and girls' manual and finger dexterities are better than boys. While the increase in BMI and weight affect static balance negatively, the increase in height and weight affect dynamic balance positively. It is thought that investigating the factors affecting motor competence will be important in evaluating the development of children and directing them to appropriate sports.
Keywords: Balance, Finger dexterity, Manual dexterity, Muscle activation.

Sağlıklı Erken Adölesan Dönemdeki Çocuklarda Motor Yeterliliği Etkileyen Faktörlerin Araştırılması

ÖZ
Amaç: Çalışmadaki amacımız, sağlıklı erken adölesan dönemdeki çocukların temel motor yeterliliklerini retrospektif olarak değerlendirmek ve etkileyen faktörleri incelemektir. **Gereç ve Yöntemler:** Çalışmaya yaşları 11.33±0.95 olan 89 çocuk dahil edildi. El becerisi Minnesota El Beceri Testi (MEBT) ile, parmak becerisi 9 Delikli Peg Test (9-DPT) ile, denge Korebalance™ Premiere ile, kuadriseps kas gücü manuel kas gücü ölçüm cihazı ile, el kavrama gücü el dinamometresi ile, kas aktivasyonu EMG Biofeedback ile değerlendirildi. **Bulgular:** Verilerin cinsiyete göre karşılaştırılmasında MEBT sağ ve sol-el yerleştirme ve 9-DPT'in arasında (sırasıyla p=0.004, p=0.041, p=0.004); yaş gruplarına göre karşılaştırılmasında MEBT'nin sol el-yerleştirme ve döndürme testleri ile sol kavrama kuvveti arasında istatistiksel olarak anlamlı fark vardı (sırasıyla p=0.010, p=0.048, p=0.025). Korelasyon analizinde yaş ile MEBT'nin sol el-yerleştirme (r=-0.336, p=0.001) ve sol kavrama kuvvetiyle (r=0.219, p=0.039); boy (r=-0.242, p=0.022) ve kilonun (r=-0.244, p=0.021) dinamik denge ile kilo ve beden kitle indeksinin (BKİ) statik denge (r=0.342, p=0.001; r=0.305, p=0.004) ve EMG Biofeedback skoru (r=0.237, p=0.025; r=0.212, p=0.046) ile korelasyonu vardı. **Sonuç:** Çocuklarda yaş ilerledikçe el becerisi ve el kavrama kuvveti gelişmekte olup kızların el ve parmak becerileri erkeklere göre daha iyidir. BKİ ve kilonun artması statik dengeyi olumsuz yönde etkilerken, boy ve kilonun artması dinamik dengeyi olumlu yönde etkilemektedir. Motor yeterliliği etkileyen faktörlerin araştırılmasının çocukların gelişimlerinin değerlendirilmesi ve uygun sporlara yönlendirilmesi açısından önemli olacağı düşünülmektedir.
Anahtar Kelimeler: Denge, Parmak becerisi, El becerisi, Kas aktivasyonu.

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INTRODUCTION

Motor competence can be defined as a person's ability to perform different motor actions, including the coordination of fine and gross motor skills necessary to manage daily tasks. Gross motor competence, in particular, plays an essential role in growth, development, and maintaining an active lifestyle (Lubans, Morgan, Cliff, Barnett, & Okely, 2010). Gross motor competence is often defined as proficiency in basic movement skills (e.g., throwing, catching, running) that are ideally learned during the preschool and early school years. These provide a foundation for children to develop more specific movement sequences, such as sport-specific and lifelong physical activity (PA) movement skills (e.g., cycling and swimming) (Hulteen et al., 2015). Fundamental movement skills (FMS) are often defined more precisely as essential stability (e.g., static balance), object control (also called manipulative, e.g., throwing), or locomotor movements involving two or more body parts (e.g., jumping) (Gallahue & Donnelly, 2007). FMS are recognized as the building blocks that lead to specific movement sequences necessary for adequate participation in many organized and nonorganized physical activities for children, adolescents, and adults. It is suggested that mastery of FMS involves the physical, mathematical, and social development of the child and the development of an active lifestyle (Gallahue & Donnelly, 2007). Recently, FMS proficiency has been suggested to interact with perceptions of motor competence and health-related fitness to predict physical activity from childhood to adulthood and subsequent obesity (Stodden et al., 2008).

The human hand is a foundation and indispensable organ that contains skills that can vary from fine motor to gross motor. High levels of hand activity are required for various daily behaviors (e.g., eating and personal care) and sports activities. Grip strength depends on the strength of the hand and forearm muscles (Subramani et al., 2015). "Hand Grip Strength" refers to the maximum force produced by the contraction of intrinsic and extrinsic hand muscles, causing the hand joints to stretch (Abdullahi, Audu, & Ter Goon, 2020). Dexterity is typically defined as the ability to synchronize small muscle movements with the eyes, hands, and fingers and is defined as the capacity to move objects quickly and coordinate fingers and is an important factor in assessing hand function (Wang, Bohannon, Kapellusch, Garg, & Gershon, 2015). Play and leisure activities, as well as work activities, require both grip strength and dexterity. These abilities are essential for adults, but they are even more important for children, whose physical and functional development is greatly affected by their dexterity development (Tissue et al., 2017). Many school activities require fine motor skills and manual dexterity. Therefore, assessment of hand functions provides important information regarding physical ability and manual dexterity (Wang et al., 2015).

Adolescence is discussed in three parts: early, middle, and late adolescence. Early adolescence is between the ages of 10-14 (Çuhadaroğlu F, 2000). One of the most critical changes in adolescence is rapid physical growth. The fastest increase in length is between the ages of 14-15 for boys and between the ages of 12-13 for girls. Weight gain in adolescents becomes apparent approximately six months after the period when it increases in length most rapidly (Parlaz, Tekgül, Karademirci, & Öngel, 2012). Girls' weight begins to grow faster than their male counterparts. The reason is that girls enter puberty earlier. Longitudinal growth is slow; transverse growth is faster. This is the period when intrinsic muscles develop rapidly. Thanks to developing manual skills, they become successful in playing ball, using basic hand tools, and playing instruments. Nerve, muscle, and joint coordination have begun to be achieved. Harmony has been achieved between muscle strength and organ development. Boys are more enduring and more robust than girls. However, this difference is slight (Çuhadaroglu F, 2000; Parlaz et al., 2012). A systematic review investigating children's gross motor competence (Barnett et al., 2016) showed that increasing age was directly related to children's gross motor competence, while healthy weight status, male gender, and good socioeconomic status had consistent correlations with only certain aspects of motor competence. A longitudinal study has shown that low motor competence is associated with increasing body mass index (BMI) over time (Vítor P Lopes, David F Stodden, Mafalda M Bianchi, Jose AR Maia, & Luis P Rodrigues, 2012). In other words, while motor competencies increase as children grow, the increase in BMI negatively affects motor abilities. Determining the normative value of fundamental motor competence such as hand grip strength, manual dexterity and finger dexterity of healthy developing children is of great importance in determining the development level of atypically developing children and detecting retardation. It is also important to direct children to the appropriate sports branch. No comprehensive research has been found on this subject in Turkiye. Our study will be guided since it includes a comprehensive evaluation. The aim of this study is to retrospectively investigate the physical evaluations (muscle strength, manuel and finger dexterity, balance, muscle activation) of 100 adolescents aged 10-13, whom we reached through the "Body Awareness" program organized by the Department of Physiotherapy and Rehabilitation within the scope of The Children's University at Bandırma Onyedi Eylül University, and to investigate what affects children's fundamental motor competence in healthy early adolescence.

MATERIALS AND METHODS

Study design and participants

This retrospective cross-sectional and descriptive study was conducted with a total of 100 children, aged 10-13, who participated in the "Body Awareness" program organized by the Physiotherapy and Rehabilitation Department within the scope of the Children's University at Bandırma Onyedi Eylül University. The program was held on the following periods: August 23-28, 2021(33 children); August 22-26 (36 children), 2022; and August 28-September 2, 2023 (31 children); therefore the data was collected on the same dates. Within the program, children's static and dynamic balance, muscle activation, muscle strength, and manual and finger dexterity were assessed. From the study, data from children with chronic diseases (1 child), those who did not complete all evaluations (6 children), and those with evaluations conducted in different years (more than one) (4 children) were excluded. Data from a total of 89 children were analyzed (Figure 1). The "Body Awareness" program was conducted at the Faculty of Health Sciences, Department of Physiotherapy and Rehabilitation application unit.

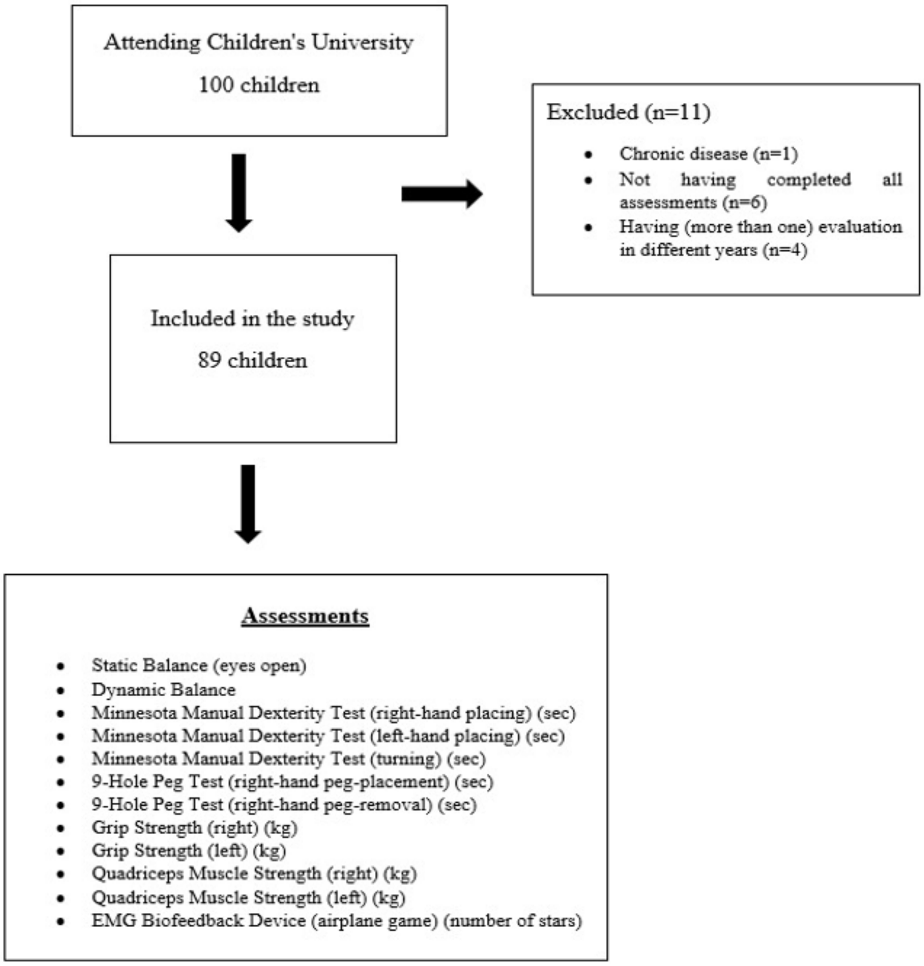

Figure 1: Flow chart

Measurements

Demographic characteristics of the children (age, height, weight, presence of any chronic medical conditions, history of surgery, etc.) were recorded. Children's manual dexterity skills were assessed using the Minnesota Manual Dexterity Test (MMDT), finger dexterity was evaluated with the 9-Hole Peg Test (9-HPT), static and dynamic balance assessment was conducted using the Korebalance ™ Premiere balance device, quadriceps muscle strength was measured using a manual muscle strength measurement device, hand grip strength was evaluated with a hand-held dynamometer, and muscle activation potential was assessed using EMG Biofeedback (airplane game).

Static and Dynamic Balance Assessment: The static and dynamic balance values of the children were assessed using the Korebalance ™ Premiere balance device (Med-Fit Systems, Inc., VA, USA). The Korebalance ™ Premiere balance device is a laboratory-based patented balance assessment and exercise training system that includes a balance platform, an integrated computer system, and a specialized software package, offering a wide range of adjustable options for testing and training on static-dynamic balance, postural control, proprioception, vestibular parameters, and more (Karatekin, Yasin, Yumusakhuylu, Bayram, & Icagasioglu, 2020). The Korebalance™ Premiere balance device provides options for static tests to assess static balance and dynamic tests to evaluate dynamic balance.

Quadriceps Muscle Strength: The Quadriceps muscle strength of the patients was measured using a manual muscle strength measurement device (Lafayette Instrument, USA) and recorded in kg/force. Maximal voluntary isometric contraction, commonly known as the "make technique," was used for muscle strength measurements, which is reported to be more reliable in the literature and frequently utilized (Roy & Doherty, 2004). Muscle strength measurements were repeated three times for both lower extremities at a 30-second interval, and the highest measurement was recorded.

Hand Grip Strength: Hand grip strength was assessed using a hand-held dynamometer (SAEHAN Corporation, Korea). Participants were instructed to sit in an upright position with their shoulders adducted, elbows flexed at a 90-degree angle, and wrists in a neutral position between supination and pronation. Measurements were taken separately for the right and left hands, and the tests were repeated three times for each hand. The average measurement of these repetitions was used for evaluation. The interpretation of measurement values was provided as a percentage of expected values for the same age and gender range in a healthy population, as determined by reference equations (Massy-Westropp, Gill, Taylor, Bohannon, & Hill, 2011).

Minnesota Manual Dexterity Test (MMDT): MMDT includes the placement of black and red discs, consisting of subtests called right-hand placing test, left-hand placing test, and turning test. The test is designed to assess gross hand dexterity, coordination, and speed (Cederlund, 1995) . In a study that investigated the validity, reliability, and reference values of the MMDT in healthy elderly individuals, the test-retest reliability was found to be high (0.79 to 0.87) (Desrosiers, Rochette, Hebert, & Bravo, 1997).

-In right-hand placing subtest, a wooden platform is placed in front of the individual, and the test begins with the individual starting from the right column. The bottom disc is placed in the top hole of the wooden platform, and the other discs are arranged in succession following the same pattern. As each column is completed, the next column is continued, and the test is completed when all the columns are filled with discs. The time it takes to complete the test is recorded.

-In left-hand placing subtest, the same procedure is followed, but the individual begins from the left column.

-In the turning test, discs with the same color are placed one on top of the other on a wooden board in front of the person. The individual uses their left hand to pick up the top disc from the right corner of the top row, turns it, and hands it to the right hand to place it back on the board. This process is repeated until the top row is completed. When the second row is reached, the disc is picked up with the right hand and turned, handed to the left hand, and placed on the board. This pattern is continued until the test is completed. The time it takes to complete the test is recorded.

9- Hole Peg Test (9-HPT): 9-HPT involves the placement and removal of nine pegs, and it is used to assess fine motor skills. It is particularly suitable for children and individuals with cognitive impairments (Ryder, 2014).

This test is applicable to individuals of all age groups, and it is an easy and fast method. For the 9-HPT, a set of pegs is evenly spread out over a perforated wooden board, and nine pegs are cut from an equal length of wooden dowel. Participants were informed about the procedure before the measurement. The measurement device was placed on the table to align with the midline of the participant's body, and the children were seated on a chair at an appropriate height. Participants were asked to remove and replace the nine pegs as quickly as possible. The test was conducted for the dominant hand, and the time it took to complete the test was recorded in seconds (s).

EMG Biofeedback: Electromyographic Biofeedback (EMG biofeedback) is a biofeedback technique that converts myoelectric activity in the muscle into visual and auditory signals through electrodes placed on the muscle. The action potential resulting from voluntary muscle contraction is displayed as a numerical value on the EMG biofeedback device. This value is typically expressed in microvolts (μV) (Basmajian, 1988). Electrodes are typically placed in the vicinity of the muscle's origin and insertion points.

The EMG Biofeedback assessment was conducted using the NeuroTrac™ ETS MyoPlus Pro2 device (Verity Medical Ltd., Romsey, Hampshire, UK) and the NeuroTrac™ EMG v5.0 software (Verity Medical Ltd., UK). In the game-based EMG Biofeedback training program, a visual image (airplane game) moved simultaneously with changes in EMG signals. Electrodes were placed on the tibialis anterior muscle. Children played the game by performing dorsiflexion and relaxation. In the game, each contraction-relaxation cycle had a specific target (star). Children were instructed to complete these cycles within specified time intervals. The number of stars collected at the end of the game was recorded.

Statistical power and analysis

After the evaluation of 89 individuals, post-hoc power analysis was performed using the G*Power (ver.3.1.9.7) program. The power of the study (1-β) was calculated as 90% with a 5% margin of error (α=0.05) for intergroup comparison analysis of the results of finger dexterity assessment.

IBM SPSS Statistics 23 (Statistical Package for Social Sciences) analysis program was used for statistical analysis. For descriptive statistics, if quantitative data provided the parametric assumption, they were given as mean and standard deviation (SD); if not, as median and minimum (min)-maximum (max) values, and qualitative data were given as frequency (n) and percentage (%) values. The suitability of the quantitative data for normal distribution was evaluated with the Kolmogorov-Smirnov Test (since the sample size was 30 and above) (Cevahir, 2020). In comparing two independent groups, the Independent samples T-test was used if the data were normally distributed, and the Mann-Whitney U Test was used if it was not normally distributed. The correlation of manual dexterity and finger dexterity with other evaluation parameters and the correlation of demographic characteristics with other evaluation parameters were evaluated with Pearson Correlation Analysis. According to the correlation coefficients, 0-0.3 was taken as weak, 0.3-0.7 as moderate, and 0.7-1.0 as strong. Statistical significance was p<0.05.

Ethical considerations

Children's University Unit obtained permission from the families of the children in this program to ensure the confidentiality of data obtained within the program, to use the information exclusively for the study, and not to share the data with third parties. This study received approval from the Bandırma Onyedi Eylül University Health Sciences Non-Interventional Research Ethics Committee (Ethics Committee No: 2032-178), and the study was conducted in accordance with the principles of the Declaration of Helsinki.

Table 1. Demographic characteristics of children

Variables (n=89)	
Age (years) (mean±SD)	11.33±0.95
Height (m) (mean±SD)	1.53±0.07
Weight (kg) (mean±SD)	43.69±8.48
BMI (kg/m2) (mean±SD)	18.73±3.31
Gender n (%)	
Girl	36 (40.4%)
Boy	53 (59.6%)
Age Group n (%)	
10-11 age group	50 (56.2%)
12-13 age group	39 (43.8%)
Distribution by Age n (%)	
10 years	20 (22.5%)
11 years	30 (33.7%)
12 years	29 (32.6%)
13 years	10 (11.2%)

SD= Standard Deviation, BMI= Body Mass Index

RESULTS

Eighty-nine children with an average age of 11.33±0.95 were included in the study at Children's University (Figure 1). The demographic characteristics of the participating children are in Table 1.

Comparing balance, manual dexterity, finger dexterity, grip strength, quadriceps muscle strength, and EMG data in children according to gender, there was a statistically significant difference in the right-hand placing and left-hand placing subtests of the MMDT and the right-hand peg-placement subtest of the 9-HPT (p=0.004, p=0.041, p=0.004, respectively). There was no significant difference between girls and boys genders in terms of other evaluation parameters (p>0.05) (Table 2).

When comparing balance, manual dexterity, finger dexterity, grip strength, quadriceps muscle strength, and EMG data in children according to age groups (10-11 years, 12-13 years), there was a statistically significant difference in the left-hand placing and turning subtests of the MMDT, in left grip strength (p=0.010, p=0.048, p=0.025, respectively). There was no significant difference between age groups in terms of other evaluation parameters (p>0.05) (Table 3).

When the correlation of manual dexterity and finger dexterity with other evaluation parameters was investigated, for the MMDT, the right-hand placing subtest had a statistically significant correlation at a weak level in a positive direction with static balance (eyes open) (r = 0.276, p = 0.009); the right-hand placing subtest had a statistically significant correlation at a weak level, in a negative direction with right grip strength and right quadriceps muscle strength (r=-0.224, p=0.035; r=-0.228, p=0.032, respectively). The left-hand placing subtest had a statistically significant correlation at a weak level, in a negative direction with right and left grip strength (r=-0.274, p=0.009; r=-0.287, p=0.006, respectively). The turning subtest had a statistically significant correlation at a moderate level, in a negative direction with the EMG Biofeedback Device (airplane game) (r=-0.353, p=0.001). For the 9-HPT, the right-hand peg-placement had a statistically significant correlation at a weak level, in a negative direction with right and left grip strength (r=-0.267, p=0.012; r=-0.225, p=0.034, respectively). There was no statistically significant correlation between the right-hand peg-removal subtest and other evaluation parameters (p>0.05) (Table 4).

When the correlation of demographic characteristics with other evaluation parameters in children was investigated, age had a statistically significant correlation at a moderate level, in a negative direction with the left-hand placing subtest of the MMDT (r=-0.336, p=0.001); age had a statistically significant correlation at a weak level, in a positive direction with the left grip strength (r=0.219, p=0.039). Height had a statistically significant correlation at a weak level, in a negative direction with dynamic balance (r=-0.242, p=0.022). Weight had a statistically significant correlation at a moderate level, in a positive direction with static balance (eyes open) (r=0.342, p=0.001); weight had a statistically significant correlation at a weak level, in a negative direction with dynamic balance (r=-0.244, p=0.021); weight had a statistically significant correlation at a weak level, in a positive direction with with the EMG Biofeedback Device-airplane game (r=0.237, p=0.025). BMI had a statistically significant correlation at a moderate level, in a positive direction with static balance (eyes open) (r=0.305, p=0.004); BMI had a statistically significant correlation at a weak level, in a positive direction with EMG Biofeedback Device-airplane game (r=0.212, p=0.046) (Table 5).

Table 2. Comparison of balance, manual dexterity, finger dexterity, grip strength, quadriceps muscle strength and EMG data in children according to gender

Variables	Girl (n=36)	Boy (n=53)	p
Age (years)	11.47±1.06	11.22±0.87	0.252[b]
Height (m)	1.53±0.07	1.52±0.07	0.424 [b]
Weight (kg)	41.99±6.69	44.84±9.38	0.098 [b]
BMI (kg/m2)	17.87±2.84	19.31±3.49	**0.035*[b]**
Static Balance (eyes open)	146 (55-613)	182 (61-1470)	0.150[a]
Dynamic Balance	1564.50 (1027-2370)	1575 (1146-2433)	0.857[a]
MMDT (right-hand placing) (sec)	66.73 (54-79)	69 (59.50-88)	**0.004*[a]**
MMDT (left-hand placing) (sec)	70.20 (58-118)	73 (59-92)	**0.041*[a]**
MMDT (turning) (sec)	68 (39.90-95)	75 (45.85-215)	0.052[a]
9-HPT (right-hand peg-placement) (sec)	11.46±1.65	12.57±1.80	**0.004*[b]**
9-HPT (right-hand peg-removal) (sec)	5.94 (4.64-16.80)	6.30 (3.11-9.85)	0.670[a]
Grip Strength (right) (kg)	20 (12-45)	20 (11-55)	0.453[a]
Grip Strength (left) (kg)	19 (11-45)	19 (8-60)	0.920[a]
Quadriceps Muscle Strength (right) (kg)	10.35 (5.90-20.30)	10.50 (7.30-24.60)	0.528[a]
Quadriceps Muscle Strength (left) (kg)	10 (6.40-18.10)	9.90 (5.40-23.40)	0.977[a]
EMG Biofeedback Device (airplane game) (number of stars)	44.50 (25-50)	47 (20-50)	0.121[a]

9-HPT=9-Hole Peg Test , MMDT= Minnesota Manual Dexterity Test, SD = Standard Deviation, EMG = Electromyography, [a]= Mann-Whitney U Test-data are presented as median (min-max), [b]= Independent samples T-test- data are presented as mean±SD, *=p<0.05

Table 3: Comparison of balance, manual dexterity, finger dexterity, grip strength, quadriceps muscle strength and EMG biofeedback data in children according to age groups

Variables	10-11 age group (n=50)	12-13 age group (n=39)	p
Age (years)	10.60±0.49487	12.26±0.44	**<0.001*[b]**
Height (m)	1.50±0.06	1.56±0.08	**<0.001*[b]**
Weight (kg)	43.34±8.90	44.14±7.99	0.657 [b]
BMI (kg/m2)	19.22±3.70	18.11±2.66	0.102[b]
Static Balance (eyes open)	217.50 (55-711)	132 (61-1470)	0.051[a]
Dynamic Balance	1587.50 (1146-2328)	1554 (1027-2433)	0.554[a]
MMDT (right-hand placing) (sec)	69.53±7.44	68.24±6.03	0.383[b]
MMDT (left-hand placing) (sec)	75.26±10.10	70.39±6.28	**0.010*[b]**
MMDT (turning) (sec)	75 (39.90-215)	68 (45.73-118)	**0.048*[a]**
9-HPT (right-hand peg-placement) (sec)	12.32±1.83	11.86±1.78	0.242[b]
9-HPT (right-hand peg-removal) (sec)	5.96 (3.11-16.80)	6.03 (4.03-8.48)	0.490[a]
Grip Strength (right) (kg)	20 (11-45)	22 (14-55)	0.123[a]
Grip Strength (left) (kg)	16 (8-60)	20 (12-45)	**0.025*[a]**
Quadriceps Muscle Strength (right) (kg)	10.45 (6.40-20.20)	10.60 (5.90-24.60)	0.960[a]
Quadriceps Muscle Strength (left) (kg)	9.70 (6.70-20)	9.90 (5.40-23.40)	0.753[a]
EMG Biofeedback (airplane game) (number of stars)	45 (20-50)	45 (23-50)	0.931[a]

9-HPT=9-Hole Peg Test , MMDT= Minnesota Manual Dexterity Test, SD = Standard Deviation, EMG = Electromyography, [a]= Mann-Whitney U Testi-data are presented as median (min-max), [b]= Independent samples T-test- data are presented as mean±SD, *=p<0.05

Table 4. Correlation of manual dexterity and finger dexterity with other evaluation parameters in children.

Pearson Correlation Analysis (n=89)	Static Balance (eyes open)	Dynamic Balance	Grip Strength (right)	Grip Strength (left)	Quadriceps Muscle Strength (right)	Quadriceps Muscle Strength (left)	EMG Biofeedback (airplane game score)
MMDT (right-hand placing)							
r	0.276**	0.124	-0.224*	-0.180	-0.228*	-0.189	0.047
p	0.009	0.246	0.035	0.091	0.032	0.077	0.662
MMDT (left-hand placing)							
r	0.090	0.083	-0.274**	-0.287**	-0.168	-0.178	-0.004
p	0.400	0.440	0.009	0.006	0.115	0.096	0.971
MMDT (turning)							
r	0.110	0.120	-0.111	-0.113	-0.090	-0.099	-0.353**
p	0.307	0.264	0.302	0.291	0.401	0.357	0.001
9-HPT (right-hand peg-placement)							
r	0.131	0.054	-0.267*	-0.225*	-0.166	-0.142	0.046
p	0.221	0.616	0.012	0.034	0.121	0.185	0.671
9-HPT (right hand peg-removal)							
r	-0.062	0.135	-0.038	-0.043	-0.045	-0.031	-0.055
p	0.565	0.207	0.723	0.691	0.677	0.775	0.607

9-HPT=9-Hole Peg Test , MMDT= Minnesota Manual Dexterity Test *=p<0.05, **=p<0.01

Table 5. Correlation of demographic characteristics with other evaluation parameters in children

Pearson Correlation Analysis (n=89)	MMDT (right-hand placing)	MMDT (left-hand placing)	MMDT (turning)	9-HPT (right-hand peg-placement)	9-HPT (right-hand peg-removal)	Static Balance (eyes open)	Dynamic Balance	Grip Strength (right)	Grip Strength (left)	Quadriceps Muscle Strength (right)	Quadriceps Muscle Strength (left)	EMG Biofeedback Device (airplane game)
Age												
r	-0.166	-0.336**	-0.183	-0.182	-0.137	-0.065	0.019	0.197	0.219*	0.034	0.053	0.067
p	0.121	0.001	0.087	0.087	0.201	0.546	0.861	0.064	0.039	0.754	0.621	0.535
Height												
r	0.037	-0.035	-0.057	-0.047	0.014	0.129	-0.242*	0.171	0.139	-0.097	-0.161	0.112
p	0.731	0.746	0.593	0.661	0.896	0.228	0.022	0.109	0.194	0.366	0.131	0.297
Weight												
r	0.135	0.076	-0.128	0.075	-0.004	0.342**	-0.244*	0.044	0.008	-0.012	-0.138	0.237*
p	0.208	0.480	0.232	0.485	0.972	0.001	0.021	0.682	0.941	0.912	0.196	0.025
BMI												
r	0.140	0.114	-0.117	0.100	-0.006	0.305**	-0.143	-0.059	-0.076	0.030	-0.071	0.212*
p	0.192	0.287	0.273	0.349	0.953	0.004	0.181	0.583	0.477	0.778	0.507	0.046

9-HPT=9-Hole Peg Test , MMDT= Minnesota Manual Dexterity Test, BMI = Body Mass Index, *=p<0.05, **=p<0.01

DISCUSSION

According to the results of our study, in which we retrospectively investigated the physical evaluations of 89 adolescents between the ages of 10-13, we found that dexterity and hand grip strength improved with age in all children and that these were related to each other. We found that girls have better manual and finger dexterities than boys. We also saw that static balance was negatively affected by BMI and weight gain, but dynamic balance was positively affected by height and weight increase. We found that age or gender had no effect on muscle activation, which we assessed with EMG Biofeedback, and that it was related to BMI, weight gain, and manual dexterity (turning test).

In a systematic review (Lubans et al., 2010) on the relationships between FMS and health benefits in children and adolescents, they found that FMS levels were inversely related to weight. Similarly, Lopes et al. (V. P. Lopes, D. F. Stodden, M. M. Bianchi, J. A. Maia, & L. P. Rodrigues, 2012), in their study with 7175 children, showed that motor coordination was inversely associated with BMI in childhood and early adolescence, and the strength of the inverse relationship increased in childhood but decreased in early adolescence (12-14 years of age). The change in muscle mass during the growth spurt may have caused this. This is explained by the appearance of rapid and differentiated individual growth (i.e., differential growth spurt and growth intensity) typical during this period. In fact, during pubertal years, it is expected that the relationship between motor coordination and BMI can be dramatically altered by the rapid and individualized changes in somatic growth that result in changes in muscle mass (boys) and adipose tissue (girls).

In the results of our study, demographic characteristics (age, weight, height, BMI) affect our measurements in different ways. We observe that weight, height, and BMI mainly affect balance. BMI and weight gain affect static balance negatively, but height and weight increase affect dynamic balance positively. The literature has researched chiefly this issue on obese children. A study (Maślanko, Graff, Stępień, & Rekowski, 2020) investigating the relationship between BMI and balance in 166 children aged 7 to 18 years found that obese children performed significantly worse than their non-obese peers on all balance tests on a moving platform. However, when a static platform was used to compare the stability of obese children with children of normal body weight, it was observed that the balance of obese children was worse (Maślanko et al., 2020). Similarly, it has been reported that children with more obesity and/or a predominance of the endomorphic component perform worse in static and dynamic postural balance tests (Guzmán-Muñoz, Valdes Badilla, Méndez-Rebolledo, Concha-Cisternas, & Castillo Retamal, 2019). In the study conducted by Hung et al. (Hung, Gill, & Meredith, 2013), it was reported that obese or overweight children walked slower and had higher postural instability in the Dual Task condition (carrying a box) compared to normal-weight children. In fact, the result of our study supports the literature. We can say that under static conditions, postural oscillations are greater in adolescents with high BMI and that this situation is especially associated with weight gain. Differently dynamic stability was positively affected by the increase in height and weight, regardless of BMI. When comparing our results with the literature, it should be taken into consideration that the majority of our study population was normal BMI children and that the number was insufficient since it was a retrospective study. Our study is a pioneer in the prospective studies that need to be done in this field for Turkiye.

Our age group covers the early adolescence period and is the year when gender-related changes begin, but the development of children is still not completed. That is why, when we separate and examine the data by age and look at the correlation, we see that only hand-related parameters affect it. We found that dexterity and hand grip strength improve with age, and as age increases, dexterity, and hand grip strength increase. This pattern of progressive strength may be explained by the similar arm and forearm muscle group development that is generally independent of the geographical area among boys and girls up to age 16 across the world (Bohannon, Wang, Bubela, & Gershon, 2017; Häger-Ross & Rösblad, 2002; Yim, Cho, & Lee, 2003). Hand grip strength showed a linear and parallel development for boys and girls until the age of 11 years, after which hand grip strength progression shows a steeper upward slope in boys than in girls, which was similar to the findings of Ahmed Omar et al. (Omar, Alghadir, Zafar, & Al Baker, 2018) ve Hager-Ross et al. (Häger-Ross & Rösblad, 2002). In our study, similar to the literature, hand grip strength increases with age. In addition, it has been observed that girls are better at manual and finger dexterity than boys. Ahmed Omar et al. (Omar et al., 2018) also found that manual dexterity, which they evaluated with the 9-HPT, was better in girls, similar to our study results. However, in a cross-sectional study conducted in Korea to determine normative data (Yim et al., 2003) similar to our population, when the dexterity of 10, 11 and 12-year-old children were compared as boys and girls, no gender differences were found in any age group. We think that in addition to physical characteristics, social factors such as culture and education may also be effective in developing skills. Therefore, theories that are always accepted, such as hand grip strength due to muscle development, may not be valid for dexterity. In addition, there was a moderate correlation between the manual dexterity-turning test time and the EMG biofeedback airplane game score.

In this game, electrodes are connected to the tibialis anterior, and children are asked to perform dorsi flexion while raising the plane and relax when lowering it. When it contracts and relaxes at the right speed and time, the number of stars it collects increases. Speed is also very important in the turning test. This relationship suggested reaction time. Manual dexterity is related to reaction time (Ingram et al., 2019). In this regard, we can gain insight into children's reaction times in clinical practice with EMG biofeedback games. Of course, the most accurate measurement is the method that objectively measures reaction time (Burghart, Craig, Radel, & Huisinga, 2018).

Our study has some limitations. The study is retrospective, and since it was not planned as a prospective study, participants distribution, such as age, gender, and BMI, is not homogeneous. Therefore, we divided the age groups into 10-11 years and 12-13 years. If the changes at each age could be evaluated separately, the stages of physical change in children could be better examined. Despite these, the power of our study is 90%, so our results have high evidence value and we think that our study can be a guide for studies to be carried out in our country because it includes a comprehensive evaluation.

CONCLUSION

Manual dexterity and hand grip strength develop with age in children, and girls' manual and finger dexterities are better than boys'. While the increase in BMI and weight affect static balance negatively, the increase in height and weight affect dynamic balance positively. In addition, the correlation between EMG biofeedback game score and manual dexterity speed may be suggestive of reaction time. In clinical practice, both measurements may give us an idea about reaction time of children. Although there are many studies examining the FMS and normative values of healthy adolescents in the world, the lack of research on this subject in our country is noticeable. Determining the normative value of basic motor competence of healthy children is of great importance in terms of determining the development level of atypically developing children and detecting retardation, as well as directing children to the appropriate branch of sports. Therefore, our study is a precursor to the prospective studies that need to be done in this field in Turkiye.

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Conflict of Interest

The author declare no potential conflicts of interest with respect to the research, authorship and/or publication of this article.

Author Contributions

Plan, design: GYG, FNY, EK, SK, EKM; **Material, methods and data collection:** GYG, FNY, EK, SK; **Data analysis and comments:** GYG, SK; **Writing and corrections:** GYG, FNY, EK, SK, EKM.

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