Normative Values of Y Balance Test and Isometric muscle strength among Saudi School children

Normative Werte von Y-Balancen-Test und isometrischen Muskelkraft unter Saudi Schulkinder

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ABSTRACT

Background To establish children-specific reference values for the Y-balance test (YBT) and Isometric muscle strength in school children of Saudi Arabia and to elucidate the relationship between YBT performance and lower limb muscle strength.

Materials & Methods Healthy School children (51 males) aged 12–15 years volunteered to participate in this study. Participants completed the YBT and maximal isometric muscle strength testing for knee extensors and flexors in a single testing session. Descriptive statistics were used to compute the YBT and muscle strength reference values. Paired t-tests were used to examine interlimb differences. Pearson's correlation coefficient was used to quantify the linear relationships between YBT distances and lower limb strength.

Results Tabulated children-specific reference values were presented for the right, left, dominant and non-dominant limbs. Participants exhibited longer distance in the posteromedial direction standing on the right ($p = 0.04$), stronger knee extensors ($p = 0.03$) on the dominant side and stronger knee flexors in the right side ($p = 0.01$) and in the dominant side ($p = 0.01$). Knee flexors muscle strength was positively related to the reach distances of the YBT in both the right and the left lower extremity ($P < 0.05$).

Conclusion The current study provided the reference value for the YBT and muscle strength for the knee extensors and flexors in male children in Saudi Arabia. The interlimb difference in YBT performance was noted in only the posteromedial direction and the dominant side had stronger knee flexors and extensors. Muscle strength of the knee flexors was positively related to the reach distance in the YBT.

ZUSAMMENFASSUNG

Ziel Bewertung spezifischer Referenzwerte für den Y-Balance-Test (YBT) und die isometrische Muskelkraft bei Schulkindern in Saudi-Arabien und die Beziehung zwischen YBT-Leistung und Muskelkraft in den unteren Extremitäten.

Materialien und Methoden Gesunde Schulkinder (51 Jungen) im Alter von 12 bis 15 Jahren konnten freiwillig an dieser Studie teilnehmen. Die Teilnehmer führten den YBT-Test und den Test für maximale isometrische Muskelkraft an Knie-Extensoren und Beugern in einer einzigen Test-Session aus. Eine beschreibende Statistik wurden verwendet, um die YBT und die Muskelkraft-Referenzwerte zu berechnen. Gepaarte t-Tests wurden verwendet, um Unterschiede in den unteren Gliedmaßen zu untersuchen. Der Pearson-Korrelationskoeffizient wurde verwendet, um die linearen Beziehungen zwischen YBT-Entfernungen und der Stärke der unteren Extremitäten zu quantifizieren.

Ergebnisse Die spezifischen Referenzwerte wurden für die rechte und die linke Seite dargestellt, jeweils für die dominanten und nicht-dominanten Gliedmaßen. Die Teilnehmer zeigten längere Distanzen in der posteromedialen Richtung auf der rechten Seite ($p = 0{,}04$), stärkere Knieextensoren ($p = 0{,}03$) auf der dominanten Seite und eine stärkere Kniebeugung auf der rechten Seite ($p = 0{,}01$) und auf der dominanten Seite ($p = 0{,}01$). Die Kniebeuge-Muskelkraft war positiv im Zusammenhang mit den zu erreichen Entfernungen des YBT-Werts in der rechten und der linken unteren Extremität ($P < 0{,}05$).

Fazit Die aktuelle Studie lieferte Referenzwerte für den Y-Balancetest und die Muskelkraft beim Kniestrecken und Beugen bei männlichen Kindern in Saudi-Arabien. Die Unterschiede in den Gliedmaßen in der YBT-Leistung wurde nur in der posteromedialen Richtung bewertet und die dominante Seite war stärker bei der Knie-Beugung und -Streckung. Die Muskelkraft der Kniebeuger hatte positive Wirkung auf die erreichten Werte beim YBT-Test.

List of Abbreviations

YBT	Y Balance Test
HHD	Hand-held dynamometer
SEBT	Star excursion balance test

Introduction

Dynamic postural control is a key sensorimotor skill that plays a significant role for the successful performance of fundamental movement and sports skills for children [1]. In order to achieve high performance in sports, an excellent dynamic balance is a prerequisite. The foundation for a lifetime of physical activity depends on the competence of motor skill development in early life and a rapidly growing interest in sports injury prevention and youth fitness testing lead to the importance of establishing reliable assessment measures [2]. An assortment of physical test batteries are presently used to assess physical fitness and sports performance and little consideration are focused, on skill based measures that oblige dynamic control in children [3].

Y Balance Test (YBT) is one of the measurement tool used to evaluate postural and dynamic balance [4]. It helps to identify lower-extremity flexibility deficits and asymmetries and might be used to predict injury risk [5–7].The practical feasibility of the instrument and its reliability (ICC = 0.88–0.99) render it a useful tool for evaluating the dynamic balance.

YBT test has been established as feasible and a reliable measure for children [3]. For the YBT to be widely implemented, either as a screening method or during the rehabilitation of children, establishment of reference values that would serve as performance criterion is paramount. Given that YBT performance might differ by culture [8], culture-specific reference values for children are needed and none currently exist for children in Saudi Arabia.

Muscle strength assessment is an integral part of the physical examination process [9]. In daily practice, clinicians require reference values of muscle strength to detect and quantify the extent of the impairment in muscle function. The ability to assess strength accurately is essential in children in order to analyse the impairments hampering the daily functional tasks [10]. Muscle strength can be evaluated using subjective [11, 12] and objective measures [10, 13]. Hand-held dynamometer (HHD) is an objective portable tool, less expensive and its relative ease of application makes it a practical tool to quantify muscle strength in children [14]. The knee strength can be measured using HHD in two ways: fixed HHD and non-fixed HHD. Both these methods are reliable and are more economical than the isokinetic dynamometer and can be performed either in sitting or supine position [15]. There are limited studies providing reference values for muscle strength obtained by hand-held dynamometry among children [16–18]. Khalid S. Almuzaini (2007) published a study on muscle function in Saudi Children and Adolescents with relationship to anthropometric characteristics during growth by using an isokinetic dynamometer [19]. Alangari, A. S et.al (2004), reported normal isometric and isokinetic peak torques of hamstring and quadriceps muscles in young adult Saudi males at different velocities with isokinetic dynamometer [20]. Reference values using Hand-held dynamometer in Saudi children do not exist.

Children seem to be at greater risk of sustaining falls and sports-related injuries than healthy young adults and in fact, lower performance levels in balance and muscle strength have been observed in children compared to young healthy adults [21, 22]. Knowledge about balance and muscle strength status may support the identification of children with an increased fall and injury risk and then the development of fall and injury-preventive intervention programs. Despite evidence demonstrating the importance of balance among children, the relationship between lower limb strength and balance is not completely understood. Investigations into the relationship of muscle strength and balance in children are conflicting as the age group, measurement protocol, and devices are not similar [3, 21, 22]. In light of the importance of dynamic balance in children, awareness of the relationship between dynamic balance and muscle strength could justify the development of more effective balance interventions.

Therefore, the objective of this study was to establish children-specific reference values for the YBT and isometric muscle strength of knee extensors and flexors in healthy school children of Saudi Arabia. A secondary aim was to examine the relationship between YBT performance and knee extensors and flexors strength.

Materials and Methods

This study was designed as a cross-sectional study in which all participants were tested in a single testing session. A convenience sample of healthy school children of males aged between 12 to 15 years old was recruited for this study. Participants were excluded if they had any lower extremity or spinal dysfunction or surgery, history of dizziness or falls, any visual or inner ear problems, any neurological dysfunctions, altered feet sensation. Participants were school students of Saudi government school, Riyadh, Saudi Arabia. All participants' parents signed informed consent forms approved by the College of Applied Medical Sciences, Human Subjects Review Board at King Saud University prior to participation [CAMS 35–34/35-Ethics Number]. Permission was granted by school authorities.

Demographic data was collected regarding age, height, weight, lower extremity length, and limb dominance (▶ **Table1**). The YBT was conducted following published protocol [4]. All testing and practice trials were performed barefoot with the left and right limbs to eliminate balance and stability provided by shoes. Barefooted subjects started the YBT with 6 practice trials in each direction prior to the formal testing. YBT practice trials were performed by participants followed by actual testing session. The participants pushed

▶ **Table 1** Characteristics of participants N = 51.

Variable	Mean ± SD	95 % CI
Age (year)	14.18 ± 0.72	13.98–14.38
Height (m)	159.45 ± 10.52	156.49–162.40
Weight (kg)	62.68 ± 19.91	57.082–68.28
BMI (kg/m²)	23.86 ± 6.16	22.12–25.59
Limb length right (cm)	87.25 ± 5.39	85.73–88.77
Limb length left (cm)	87.22 ± 5.37	85.70–88.72

Note: Limb length: Measured in supine position from anterior superior iliac spine ASIS to the most distal aspect of the medial malleolus the reach indicator with one foot in the anterior (A), posteromedial (PM), and posterolateral (PL) directions while standing on the other foot on the central footplate. The order of the practice trials was a right anterior reach, left anterior reach, right posteromedial reach, left posteromedial reach, right posterolateral reach, left posterolateral reach.

The formal testing trials were performed in the same order as the practice trials with 3 trials performed in each direction. In each trial, subjects were asked to reach as far as they could with the reach foot while keeping the reach foot in contact with the reach indicator then return to the starting point while still balanced on the stance limb. The maximum reach distance was recorded to the nearest 0.5 cm in each reach trial. The maximum reach distance of the 3 formal trials in each direction was used for the analysis. A trial was classified as invalid if the participant did not return to the starting position, failed to maintain a uni pedal stance on the platform, kicked the reach indicator with the reaching foot to gain more distance, stepped on top of the reach indicator for support. If an invalid trial occurred, the data were discarded, and the subject repeated the trial.

Reach distances recorded in cm were also normalised to each subject's leg length by dividing the reach distance by limb length then multiplied by 100 to account for the influence of leg length on test performance [23, 24]. Participants' lower-limb lengths were bilaterally measured in the supine position to the nearest half centimetre from the anterior superior iliac spine to the distal part of the ipsilateral medial malleolus. Normalised Composite reach distance was computed for each leg as the sum of the maximum reach distances (in cm) in the 3 directions divided by 3 times limb length then multiplied by 100.

The maximum isometric strength of the bilateral knee extensors and flexors were assessed using a handheld dynamometer (Lafayette Manual Muscle Test System, model 01165, Lafayette Instruments, Lafayette, Indiana, USA). Participants were positioned in sitting with the hip and knee at 90 degrees of flexion. The handheld dynamometer was placed just proximal the ankle joint anteriorly for the knee extensors and posteriorly for the knee flexors. The lever arm from the centre of the dynamometer's pad to the lateral femoral epicondyle was measured and used in converting the peak force value (in Newton's) recorded by the dynamometer into torque value in Newton-meter (Nm). Participants were asked to gradually build their isometric force against the examiner's resistance during knee extension and flexion to reach their maximum force then hold their maximum contraction for 5 seconds. When the subject was pushing against the resistance of the examiner, he was given appropriate command and instructions to avoid any movement in the knee joint. Participants performed three trials for each muscle group, with a 30-s rest between trials. The mean torque value of the 3 trials for each muscle group was used in the data analysis.

Statistical analysis

Reference values were provided by computing means, standard deviations and 95 % confidence interval (CI) for each reach direction in the YBT and also for the knee extensors and flexors strength. Paired t-tests were used to examine interlimb differences in YBT performance and knee extensors and flexors strength. Pearson's correlation coefficients were used to quantify the linear relationship between reach distances during YBT and the strength of the knee extensors and flexors. All analyses were performed with IBM SPSS Statistics 22 (IBM Corp, Armonk, NY) and the significance level was set at 0.05.

Results

51 male children within the age group of 12–15 years participated in this study. The characteristics of the participants regarding their age, height, weight, BMI, and limb length are presented in ▶ **Table 1**. Reference values for the YBT are expressed as a percentage of leg length in ▶ **Table 2**. Participants showed no inter-limb differences right versus left or dominant versus non-dominant leg in all directions of the YBT except in posteromedial direction right versus left, ($p = 0.04$) with longer reach distance while standing on the left side (▶ **Table 2**).

Reference values for the knee extensors and flexors strength are presented in torque values (Nm) and also torque values normalised to body mass (Nm/Kg) in ▶ **Table 3**. Inter-limb comparisons of normalized strength values (Nm/Kg) revealed stronger knee extensors in the dominant side compared to the non-dominant side ($p = 0.03$), stronger knee flexors in the right side compared to the left side ($p = 0.01$), and stronger knee flexors in the dominant side compared to the non-dominant side ($p = 0.01$) (▶ **Table 3**). No inter-limb difference was detected between the right and left knee extensor strength (▶ **Table 3**).

Correlational analysis between YBT reach distance and muscle strength revealed a significant positive correlation between the strength of the right knee flexors and the YBT right posteromedial, right posterolateral and the right composite reaches score ($p < 0.05$) (▶ **Table 4**). The left knee flexors strength also showed significant positive correlation with the YBT left anterior, left posteromedial, left posterolateral and the left composite reach score ($p < 0.05$) (▶ **Table 4**). Quadriceps strength in the right and left sides did not correlate with any of the YBT reach distances (▶ **Table 4**).

Discussion

The purpose of this current study was to provide children-specific reference values for the YBT and peak muscle force of school children in Saudi Arabia and also to examine the relationship of knee extensor and flexor muscle strength with dynamic balance. The results of this investigation will provide better insight into the interpretation of the YBT and muscle strength testing results in daily clinical practice and the presented reference values could be used as a benchmark for screening purposes or in the rehabilitation of injuries of children.

No literature exists in regard to YBT scores of children either from Saudi Arabia or neighbouring countries with similar culture and lifestyle. The YBT reference values in this study were presented for the right, left, dominant, non-dominant legs and also for the average of the 2 legs. Faigenbaum et.al (2014) analysed 188 students of first to fifth-grade children within age group of 6.9–12.1 years. The reach distances are lower when compared to what is reported in the current study. The participants in this study were barefooted in comparison with above study where participants

▶ **Table 2** Reference values for Y Balance Test (expressed as percentage of leg length, %LL).

Variable	Mean ± SD	95 % CI	Mean Interlimb Difference (95 % CI)
Anterior %LL			
Right	76.60 ± 9.15	74.03–79.18	1.78 − 0.25 to 3.81
Left	74.82 ± 8.01	72.57–77.07	
Dominant(D)	75.91 ± 7.95	73.68–78.15	0.41 − 1.68 to 2.50
Non-dominant(ND)	75.51 ± 9.29	72.90–78.12	
Average	75.71 ± 7.80	73.52–77.91	
Posteromedial %LL			
Right	99.70 ± 11.84	96.37–103.03	− 2.36 − 4.60 to − 0.12 *
Left	102.06 ± 11.49	98.83–105.30	
Dominant (D)	99.91 ± 11.75	96.60–103.21	−1.95 − 4.22 to 0.32
Non-dominant(ND)	101.86 ± 11.62	98.59–105.13	
Average	100.88 ± 10.97	97.80–103.97	
Posterolateral %LL			
Right	104.74 ± 10.39	101.81–107.66	− 0.78 − 2.70 to 1.14
Left	105.51 ± 10.30	102.62–108.41	
Dominant(D)	104.54 ± 10.44	101.60–17.48	− 1.17 − 3.08 to 0.74
Non-dominant(ND)	105.71 ± 10.24	102.83–108.59	
Average	105.13 ± 9.77	102.38–107.87	
Composite %LL			
Right	93.68 ± 8.79	91.21–96.15	− 0.45 − 1.71 to 0.81
Left	94.13 ± 8.83	91.65–96.62	
Dominant(D)	93.45 ± 8.48	91.07–95.84	− 0.90 − 2.15 to 0.34
Non-dominant(ND)	94.36 ± 9.11	91.80–96.92	
Average	93.91 ± 8.52	91.51–96.30	

CI = confidence interval; %LL = percentage of leg length; * Significant interlimb difference ($p < 0.05$)

wore regular sports shoes. Participants in the current study were older than those in Faigenbaum et.al [3] study and include only male participants. In addition to differences in footwear and age, gender cultural and lifestyle differences between the 2 cohorts might explain some of the difference in YBT performance, was reported by Butler RJ et.al [8].

In the current study, no differences were noted between the limbs except in the posteromedial direction. There is the significant inter-limb difference between right and left leg, in a posteromedial direction ($p < 0.05$), but no differences were noted when comparing the dominant versus non-dominant limb. Children in the current study had better dynamic balance while standing on the left limb in comparison to the right in posteromedial direction. It has been suggested that the non-dominant limb plays an active role of postural stabilisation while the dominant limb performs the actions of mobilisations [25]. 92 % of children in the current study reported their left leg to be their non-dominant leg, which might explain the superior performance standing on the left compared to the right. Alnahdi et al. (2015) reported a similar pattern of inter-limb difference in YBT among adults of Saudi Arabia [23]. Hertel J et.al (2006) concluded posteromedial component of the SEBT is highly representative of the performance of all 8 components of the test in limbs with and without chronic ankle instability [26].

In this study, reference values for muscle strength Nm and normalised muscle strength values (Nm/Kg) were obtained from knee extensors and flexors using a handheld dynamometer (▶ **Table 3**). This study aimed to generate children specific normative scores using hand-held dynamometer and standard procedures of testing. This normative reference score helps to identify impairment in muscle strength and can be used and set targets for age-appropriate patients during rehabilitation. The strength values were portrayed from a wide range of age groups and variations in the measuring units such as newton, pound, and kilograms but not in torque values (N-m) [27]. Height, weight and maturational level play a role in the variation of muscle strength [10]. Considering the different growth factors that influence the muscle force, where typical growth acceleration is seen in boys were chosen to establish age-related specific normative values [14]. As height plays a role in the muscle strength, the lever arm distances were used to assess the muscle strength with the observed torque values (N-m) rather than kilograms, Newton's as compared to previous studies[28, 29]. Body mass also correlates with muscle force, therefore, torque values were normalised to body mass (Nm/Kg). Macfarlane et.al (2008)

▶ Table 3 Reference values for observed muscle torque values (Nm) and normalized muscle torque values (Nm/Kg).

Variable	Mean ± SD	95 % CI	Mean Interlimb Difference (95 % CI[a])
Right knee extensor strength (Nm)	85.56 ± 34.54	75.84–95.28	0.034 −0.03, 0.10
Left knee extensor strength (Nm)	84.46 ± 36.90	74.08–94.84	
Right knee extensor strength (Nm/Kg)	1.39 ± 0.41	1.28–1.51	
Left knee extensor strength (Nm/Kg)	1.36 ± 0.39	1.25–1.47	
Dominant knee extensor strength (Nm)	86.69 ± 34.90	76.87–96.50	0.07 0.006, 0.13 *
Non-dominant knee extensor strength (Nm)	83.34 ± 36.49	73.07–93.60	
Dominant knee extensor strength (Nm/Kg)	1.41 ± 0.42	1.30–1.53	
Non-dominant knee extensor strength (Nm/Kg)	1.34 ± 0.38	1.23–1.45	
Right knee flexor strength (Nm)	54.51 ± 16.28	49.93–59.09	0.06 0.03, 0.09 *
Left knee flexor strength (Nm)	50.95 ± 14.86	46.77–55.13	
Right knee flexor strength (Nm/Kg)	0.90 ± 0.20	0.84–0.95	
Left knee flexor strength (Nm/Kg)	0.84 ± 0.18	0.79–0.89	
Dominant knee flexor strength (Nm)	53.93 ± 16.11	49.39–58.45	0.04 0.009, 0.07 *
Non-dominant Left knee flexor strength (Nm)	51.54 ± 15.17	47.27–55.81	
Dominant knee flexor strength (Nm/Kg)	0.89 ± 0.20	0.83–0.94	
Non-dominant knee flexor strength (Nm/Kg)	0.84 ± 0.18	0.79–0.90	

CI = confidence interval; [a] interlimb comparisons were conducted using the normalized strength values (Nm/Kg); * significant interlimb difference ($p < 0.05$)

▶ Table 4 Correlation between the YBT reach distance %LL and knee extensors and flexors strength (Nm/Kg).

Variable	Right Anterior	Right Posteromedial	Right Posterolateral	Right Composite
Right knee extensor strength	0.183	0.210	0.156	0.219
Right Knee Flexor strength	0.243	0.384 *	0.285 *	0.369 *
Variable	**Left Anterior**	**Left Posteromedial**	**Left Posterolateral**	**Left Composite**
Left Knee extensor strength	0.191	0.255	0.176	0.237
Left Knee Flexor strength	0.342 *	0.474 *	0.309 *	0.429 *

%LL = percentage of leg length; * Significant relationship ($p < 0.05$).

reported findings of lower extremity muscle strength with the similar protocol of this study. Knee flexion and extension torque values reported were less in comparison to this study as the participants were between the age 6 and 8 years[29].Generally, the strength differences emerge at an average age of 10–12 years, so the results of normative data must be considered with respect to chronological age of children. A recent study done by Hebert et.al (2015) reported normative data similar to this study, with peak torque values slightly higher than our study and variation can be associated with the use of a strap for stabilisation [27]. Peak torque values of extensors and flexors are reported by Khalid S. Almuzaini (2007) at different velocities with different age groups. The strength values of Saudi children were reported by using electromagnetic dynamometer rather than HHD, reducing the clinical utility as most of the clinics lack the access to the isokinetic devices [19]. So our study helps to provide the normative data of peak isometric torque values of HHD.

The inter-limb comparison of normalised strength values (Nm/Kg) exhibited stronger knee extensors and flexors in the dominant side compared to the non-dominant side and stronger knee flexors in the right side compared to the left side but no inter-limb differences were detected between right and left knee extensor strength. The pattern of inter-limb differences could be attributed to sampling characteristics where 92 % of the samples were right side dominant. A study conducted by Alangari et.al (2004) reported that isometric flexion strength was 9.3 % higher in the right leg compared to the left ($p < 0.0 1$), while there was no significant difference between the two legs in extension. The results were similar with our study, but the sample of the study included young adult population and isometric force analysed using electromechanical dynamometer [20]. Other studies reported no strength difference between dominant and non-dominant limb [30, 31].

In the present study, significant positive associations were found between YBT performance and the strength of the knee flexors muscle in the weight bearing limb, but no significant association with knee extensors. The potential role of the hamstrings in controlling the pelvis over the weight bearing lower extremity might explain this significant positive relationship. Results from previous studies investigating the relationship between strength, the dynamic balance was conflicting and no evidence examined such relationship in children are available. In adults, Kyu Lee et.al (2014&2015) reported a significant positive or negative correlation of Y balance score with knee flexor strength of adult women [32]. Similar pattern of correlation was also reported in middle and old age women [33]. Granacher U et.al (2012) investigated the relationship between variables of static and dynamic postural control and isometric and dynamic muscle strength among prepubertal children. No statistically significant associations were found between measures of postural control and muscle strength [21]. Another study by Booysen MJ et.al (2015) examined the relationship of eccentric strength and power with dynamic balance in male footballers [33]. No significant relationship was observed between eccentric strength knee flexors and normalised reach scores but a moderate relationship was observed with non-dominant knee extensors. The results of this study can be associated with the type of sport and training [34].

The current study established children-specific reference values for the Y-balance test and isometric torque scores of knee extensors and flexors in healthy school children aged 12–15 years in Saudi Arabia. Further efforts are needed to establish reference values for the same outcome measures in different age groups and isometric muscle torque values of different muscles to enhance the clinical usefulness of these measures in daily clinical practice.

The study has a few limitations. Firstly, we recruited only male sample in the study limiting the generalizability of results to male children. Secondly, we chose a standardised order for testing rather than counterbalancing the limbs to reduce the order error. And the design of the study was cross-sectional and therefore casualty cannot be assumed. The range of motion of lower extremity joints was not measured in the current study to examine its influence on YBT performance but the participants were healthy and none of them had any lower extremity complaints. The strength values reported in this study were relatively low compared to the previously published values and this can be attributed to the absence of a fixation of the upper body and lack of stabilisation while using HHD.

Conclusion

The current study provided a reference value for the YBT and muscle strength for the knee extensors and flexors in male children in Saudi Arabia. The inter-limb difference in YBT performance was noted in only the posteromedial direction and the dominant side had stronger knee flexors and extensors. Muscle strength of the knee flexors was positively related to the reach distance in the YBT.

Conflict of interest

None of the authors has any competing interests.

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