ORIGINAL ARTICLE

TRUNK ANTERIOR FLEXIBILITY IN ADOLESCENTS AFTER HEIGHT GROWTH SPEED PEAK

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SUMMARY

Trunk anterior flexibility (TAF) is a major component of clinical and physical ability tests and it is used as an indicative of vertebral function. The most used test for its quantification is the seat-and-reach (SRT), which considers hands touching feet as normality standard, with analysis criteria and parameters that are independent of variables. In this study, TAF was investigated in teenagers, after the occurrence of the height growth speed peak compared to gender, performance speed, and anthropometric data. Rates were provided as centimeters; body weight in kg. One hundred two adolescents took part of the study, being 45 females and 57 males, with ages between 16 and 20 years. The results suggest that gender factor, anthropometric data, and test performance speed influence flexibility rates; the evaluation of vertebral function cannot have SRT for reaching feet as a normality criterion, and that fast speeds lead to better results. In brief, results suggest that touching feet is a criterion ruling out a normal vertebral function in approximately 50% of the adolescents. Thus, the criterion used for making a decision regarding referring a teenager to recover higher flexibility rates must be reviewed.

***Keywords:** Pliability; Joint instability; Adolescent; Physical examination.*

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INTRODUCTION

Joint motility refers to joint range of motion, and manifests differently in children,[1,2] in adolescents,[3] in adults[4,5] and tends to drop with age.[2,6] In adolescents, specifically, it progressively drops until puberty and increases during adolescence, reaching a plateau and then reduces back.[7,8] It also varies according to gender, with women having more generalized joint flexibility.[2,9]

Studies on the differences in flexibility among individuals has taken into account some factors such as anthropometric measurements[10], body structure[8], genetic factors[1], cultural factors[8] and pathological factors[5]. Therefore, the characterization of an individual's flexibility is multifactorial.

Flexibility is regarded as a major component of physical ability and good physical health, particularly the anterior flexibility of the trunk (AFT), highlighted by experts on the matter.[2,11,12]. It is an important part of clinical examination, counting on several methods usually employed for assessing it [5,11] Overall, TSA is the most commonly accepted[5], because it enables to identify flexibility of the posterior muscular chain's muscles [11] their functional loss, and also, as an indicative of vertebral function[13] to provide a follow up on patients' progress[4]. Its accuracy was corroborated by Baldaci et al.[11] when comparing three different tests intended to measure flexibility of ischiotibial muscles on female university students.

When identifying insufficient AFT rates, muscle stretching is a routine procedure applied at physical therapy clinics and in gyms for recovering spinal flexibility's mechanical and functional characteristics [14]. Thus, understanding intervenient factors on joint motility, specifically on a population of adolescents after the height growth speed peak (HSP) will avoid the search for physical capacities that are incompatible to this body growth phase. In Brazil, few data are available enabling the characterization of teenagers' health status. Thus, the characterization of the AFT in this population should contribute to the diagnosis and follow up of adolescents' health status after HSP.

Alter[7] mentions the study by Johns and Wright in which joint motility components were quantified and the joint capsule and ligaments were pointed out as the most important factors for characterizing flexibility, accountable for 47% of the stiffness, followed by muscular fascia (41%), by tendons (10%) and by skin (2%). Thus, it is justified that joint motion may be limited by soft tissue apposition, by shocking joint surfaces conformation, by ligaments and muscles essentially acting as ligaments, by the joint capsule, and also by skin resistance to extension and by friction with tendinous sheath.

Extreme ranges of motion are typical in patients with Benign Joint Hyper motility, a non-pathological phenomenon, which may develop sequels and predispose to characterized joint pain [15]. Among many causes, the inherited disorder of collagen synthesis is included, which is a complex genetic characteristic with multiple genes contributing to phenotype and hyper motility degree [16].

It is well-established that females' joints have a larger range of motion for different age groups.[2,9,12,17] On the other hand, many studies reported specific results regarding differences between genders [8,12,18]. Guedes and Guedes[8], in a study involving children and adolescents, reported a trend towards AFT increase among women after the age of 15. Lamari et al.[12] when assessing SFT in a Japanese community, represented by 241 individuals with ages ranging from 7 to 90 years, did not find any significant differences between genders. Minkler and Patterson[18] report that women have a wider flexibility on ischiotibial muscles.

"Normal" age-related changes are those matching to a pattern in individuals of a particular age and ethnical group. What is "normal" for a young spine is different from what is "normal" for an elderly [19]. In general, there is a consensus among most of the researchers concerning to articular diminished motion (ADM) with age, regardless of the gender. Studies by Lamari et al.[2] with 1120 pre-school children of both genders, ages ranging from four to seven years, reported that even in this narrow age group, only 14% reached maximum flexibility on AFT variant, and also, in the analysis of the

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same variant in a Japanese community, it was identified in only 3% of the individuals, and the difference was not significant between genders [12].

The HSP in girls is at its maximum level at 11.5 years old, and, in boys, it reaches a peak at 13.5 years. In the intermediate period, between 14 and 16 years old, height growth is maximum, with changes observed on body shape and composition[20]. Thus, men and women do not differentiate from each other just regarding primary and secondary sexual characteristics, but also regarding their constitutional, anatomical and physiological measurements, which may interfere on joint range of motion. Hence, when analyzing a population such as adolescents who have been through major changes, especially physical, one must consider all these aspects when assessing AFT. Although Grenier, Russel and Mcgill[21] had proven a lack of association between AFT rates and anthropometric data, based on data concerned to 72 male and female individuals with ages ranging from 20 to 51 years.

In this context, we noticed the lack of studies quantifying the AFT rate in adolescents, exclusively after HSP, and comparing it to anthropometric measurements, age and gender at slow and fast speeds.

CASE SERIES AND METHOD

Data relative to 102 adolescents (45 girls and 57 boys) between 16 and 20 years old were obtained. In average, the girls were 18.2 years old (sd = 1.0 year), and the boys were 18.6 years old (sd = 1.1 year), 62.3cm (sd = 6.44cm) and 175.33 cm (sd = 6.67cm) high, body weight 59.6 kg (sd= 14.8) and 70.6 kg (sd= 12.1), respectively. Those refusing to participate and/ or presenting any significant postural change or physical disability were excluded from the study. This study was approved by the Committee on Ethics in Research with Human Beings, Medical College, São José do Rio Preto, in 03/08/99, file nr. 663/99.

The material employed included a wooden stadiometer with cursor; 0.1 cm precision scale; 50 cm rule; 1.50 m measuring tape in 0.1 cm increments; 80 and 120 cm anthropometers; wooden bench with adjustable height; L-shaped aluminum feet support, with a 40-cm flat lower portion perpendicular to the anterior one 30 cm high, providing support to feet.

Data were collected on an individual basis and, for obtaining measurements, the individual must remain with bare feet and no clothes on the region to be measured.

Linear Anthropometric Measurements

a) Height: distance between the vertex and plantar region, obtained with the stadiometer (cm), with the individual standing up on equipment's base, head oriented to frontal plane, upper limbs (UULL) in parallel to the body; legs closed, with posterior surfaces of heels, pelvic waist, scapular waist and occipital region touching the measuring scale. Measurements recorded in inspiratory apnea;

b) Span (SPN): distance in cm between the 3rd finger of the right hand and the 3rd finger of the left hand. The individuals were asked to stand up, arms in abduction forming a 90^{o} angle with the trunk, elbows in extension and forearms in supine position;

c) Trunk-head Height (TH): distance between the vertex and bench seat, obtained with the anthropometer, sitting in an adjustable bench, with ankle-knee and knee-thigh-femur joints in right angle position (90^{o});

d) Length of the right lower limb (LL): distance between trochanter and the floor, obtained with the anthropometer, in upright position, closed legs, relaxed shoulders, and UULL in parallel to the body;

e) Length of the right upper limb: distance between acromion and the 3rd finger, obtained with the anthropometer, at the same position as described for measuring the length of the right lower limb.

Anterior Flexibility of the Trunk (AFT)

AFT was obtained by TSA with the individual sitting over ischiatic region, facing the equipment, with extended knees and supported by the investigator, with soles on equipment's perpendicular surface. Upper limbs in extension towards feet support surface, one hand over the other, matching fingertips and hand palms turned down. For obtaining the results, the individual extended ahead, reaching the longest distance as possible towards feet, in a slow and smooth fashion. In a second moment, this measurement was obtained by following the same procedure as described above, but in a fast speed. The reached distance was recorded at each 0.5 cm, determined by the maximum reached position and maintained for two seconds at both speeds.

The investigator, positioned at the right of each individual, pointed the reached position on the scale. The achieved result corresponds to the distance (cm) between fingertips and sole level. Measurements of the distance above feet were recorded as positive, indicating a performance not sufficient to touch them, and those beyond feet were recorded as negative. A zero score was attributed whenever an individual touched the support surface.

With the intention of reproducing the way in which AFT is performed in daily clinical practice, the individuals of this study received guidance on how to behave when performing the test, and then, perform it only once, with no previous warm-up.

Twelve individuals were selected for checking TSA reproducibility at the slow and fast speeds. Tests were performed again and compared to the first ones by means of the sign test, which showed no difference between groups, both for fast TSA (p = 1.00), and slow TSA (p = 0.29).

A data base was built for descriptive and inferential statistical analysis. The averages obtained by TSA at slow and fast speeds were compared by variance analysis (ANOVA) and by the t-test. The significance level was established at 5% for null hypothesis ruling out. The Pearson correlation analysis was employed to check the correlation between a same individual's data at both speeds. The multiple regression analysis was used for identifying the variables interfering on movement.

RESULTS

The results achieved by TSA at slow speed ranged from –12.00 to 33.00cm, average 5.25cm (sd =7.66cm); and, at fast speed, from –17.00 to 24.00cm average 1.88cm (7.85cm). The descriptive analysis, at slow speed, shows that 25% reached, at most, a distance of 10.25cm above feet, and 25% else reached beyond feet, at fast speed, the results are shown to be better at fast speed, when approximately 50% of the teenagers are able to touch feet. However, when performing the movement at slow speed, above 60% show to be unable to touch feet. The average flexibility value for the whole group is higher than zero centimeter, that is, do not touch feet both at slow speed ($p < 0.0005$), and at fast speed ($p < 0.008$). Values above 12 cm above feet were reached by 90% of the teenagers. At fast movement, 10% of the less flexible teenagers reach at most 15 cm above feet, and 10% of the most flexible ones reach at least about 8 cm below feet.

The results described on Table 1 suggest a higher percentage of adolescents not able to touch feet at slow speed conditions (66.7%; $p<0.0005$), that is, hypo mobile condition, represented by 71.1% ($p= 0.004$) and 63.2% of the teenagers ($p = 0.032$), but not different at fast speed.

The Pearson's linear correlation analysis for each speed reported significant correlations, but not strong, between slow and fast speeds regardless of gender ($r=0.95$; $p<0.0005$), according to the illustration on Figure 1, when different degrees of dispersion points' stretching are seen. Thus, longer UULL and LLLL indicate higher AFT rates in both genders, regardless of the performance speed. The same happens with height only for females, as well as on span, this one only at fast speeds. Body weight and trunk-head height are not correlated to TSA. This is between anthropometric variables assessed, only height, span, limbs length show a significant and positive correlation. Limbs lengths are positively and significantly correlated to the rates at slow and fast speeds ($0.26\leq r\geq 0.36$). However, height and span are equally correlated only in females.

Analyses performed with the coefficients of the Multiple Regression Analysis for anthropometric data on AFT rates, for each gender in order to explain the movement effect as a result of the variables, indicate that, in boys, the longer LLLL lead to lower AFT rates. On the other hand, longer limbs, both upper and lower, and a smaller span lead to lower AFT rates only when TSA is performed at a fast speed. Thus, for girls, there is significance for lower AFT rates with increasing heights, regardless of the speed, and with increasing trunk-head height only at slow speeds, and also with decreasing trunk-head height at fast speeds (Table 2).

DISCUSSION

We focused an age group that has been going through big changes, especially those of physical nature [8], which, since then, will present characteristics that are closer to adults', since between the ages of 14 to 16, growth is at its maximum pace. This was the condition that suggested how to choose this study population.

This study is justified by the need of obtaining reliable AFT reference markers in adolescents, which will contribute to the work of many healthcare professionals both at clinical practice and at scientific trials. Factors justifying the need of producing studies intending to better understand good health associated to AFT rates; of preventing postural changes, particularly on spine, which becomes evident by the large number of studies addressing this region of the body [12,19,21-23]

The adaptive muscular shortening or stretching compromises spine's ability to work appropriately regarding stabilization, trunk and thoracic box movements control during upper ends and AFT activity [19].

Therefore, healthcare professional's interest is expected on characterizing spinal flexibility in a specific age group, such as in Brazilian teenagers, once cultural and social contexts also reflect on physical qualities. Nevertheless, no studies involved the investigation of these variables exclusively in teenagers after HSP. In Brazil, there is no systematic program designed to fulfill these needs, nor can we count on previous experiences reported by studies for comparison purposes.

That information can constitute important markers of physical health levels in a young population. Thus, among the many reasons encouraging researchers to develop studies in this area is the concern with primary prevention and the promotion of health in adolescents.

Regarding anatomical differences, we should consider that, after puberty, boys usually present with proportionally longer LLLL to height[24], a portion of such discrepancy on the results achieved in girls could explain their skeletal morphology differences, having in mind their apparent involvement in this motor test's results. Therefore, by determining absolute values or considering TSA as a subtle variable, touching hands on feet or not, it becomes evident from this study that this way of characterization is impossible, once the results showed to be continuous variables in this population. These data are corroborated by the present study.

Speeds analyses showed that the test, at slow speed, suggests that over 60% of this population cannot reach the feet. Those evidences show not only important data for characterizing what is expected for adolescents, but also a perspective for an older population, that is, the trend suggesting that in young adult and old populations the threshold for these rates is not reached, once literature shows that flexibility decreases with age.[2,6,19] In this health concept, not being ill is not enough, it is necessary to present evidences ruling out risk factors for diseases or their erroneous characterization.

Considering that AFT by touching hands on feet is a good marker of a good health status regarding spine [2,11,12], which constitutes a routine in the assessment of postural spinal pain complaints. By assessing it, decisions are made about the most appropriate treatment. Frequently, these patients are referred to physical therapy practices or to the gym, and submitted to long-lasting treatments intending to enhance flexibility, without taking into account that hyper motility can bring damages to health [15]. AFT quantification in this age group is not clear from available literature.

Variable	Gender	Hyper mobile		Hypo mobile		Total		p value**
		n	%	n	%	n	%	
TSA (L)	F	13	28.9	32	71.1	45	44.1	0.004
	M	21	36.8	36	63.2	57	55.9	0.032
	total	34	33.3	68	66.7	102	100	<0.0005
				*p value = 0.392				
TSA (R)	F	21	46.7	24	53.3	45	44.1	0.766
	M	32	56.1	25	43.9	57	55.9	0.855
	total	53	52.0	49	48.0	102	100	0.767
				*p value =0.340				

*Flexibility versus gender; ** Hyper mobile versus hypo mobile

***Table 1** - "t"-test and "Sit-Reach" test results performed at slow speed (S) and fast speed (F) related to gender.*

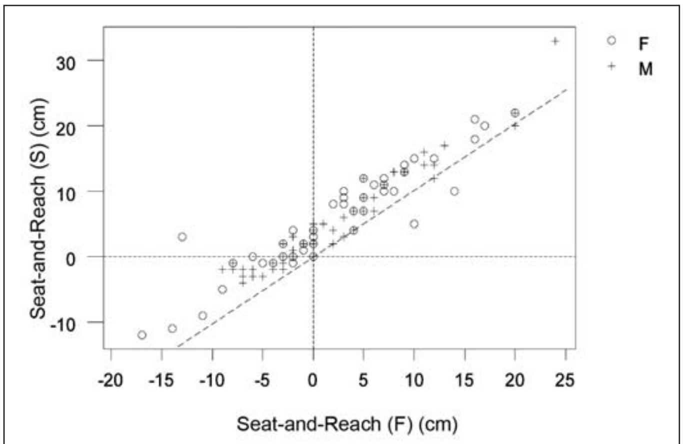

***Figure 1** - TSA dispersion diagram at fast speed x slow speed (r = 0.95; p < 0.0005).*

Variable	Gender	Height	Weight	UULL	LLLL	TC	SPAN
Anthrop							
TSA (S)	F	1.04*	0.15	1.14	-0.27	-1.01*	-0.88
	M	-0.05	-0.14	0.90	0.85*	-0.08	-0.63
TSA (F)	F	1.33*	0.15	0.92	-0.29	-1.45*	-0.86
	M	-0.09	-0.17	1.23*	0.77*	-0.08	-0.71*

***Table 2** – Multiple Regression Analysis Coefficients for anthropometric data on anterior trunk flexibility rates.*

Overall, the results of the descriptive analysis show that these adolescents are unable to touch the hands on feet level or beyond. However, the speed aspect produced different results, showing that flexibility is lower when the assessment is performed at slow speeds. On the other hand, at fast speed, this was higher but still couldn't reach the feet. It is possible that the fast movement impulse combined to gravidity and to trunk weight produce better results, in addition to further enhance trunk's flexor muscles, which does not happen at slow speeds. Nevertheless, the studies found in literature did not specify the speed factor.

In the same age group we find adolescents exceeding feet level at 17 cm, meaning that these are extremely hyper motive individuals. On the other hand, we find others 33 cm above feet level, who are extremely hypo mobile individuals. This range comprehends 50 cm on AFT range of motion scale, extremes deserving the same level of concern both for prevention and therapy, and both for hyper motility [9,17,24], and hypo motility conditions[18,23].

Results show that 90% of this teenager population can anteriorly flex the trunk at least 20.8 cm above feet level. On the other hand, 10% of them flex at least 3.7 cm beyond feet level. Those discrepancies show that even in a narrow age group population, proportional between genders, we are still faced with highly variable quantitative values, suggesting that those divergences point toward the existence of intervenient factors associated to gender,[6,18] to body constitution[8,25], to physical structure[10], and to genetic determinants[1].

When assessing any human characteristic, the normality concept for a variable is supported by the frequency of its values occurring in a representative sample of a population with identical characteristics. Thus, the analysis of data obtained in the present study enabled capturing criteria and parameters for the teenager population after HSP, particularly in Brazilian adolescents.

In this population, no significant difference was found between genders. On the other hand, other studies suggested that female joints present with wider ranges of motion at different age groups[2,17]. A study involving Brazilian children and adolescents reported a trend of AFT increase among girls after the age of 15 [8]. In the present study, 80% of the boys showed to be able to flex at least 11.9 cm, while the girls reached at least 11.6 cm, and only 10% of them presented with values beyond feet level.

A factor so far little commented in studies about AFT has been the speed in which the assessment must be applied. In the present study, we found that the difference was highly significant between flexibility rates at slow and fast speeds, regardless of gender. Therefore, because movement is performed quickly, this implies in a greater AFT. Therefore, we suggest that especial attention should be given to speed at test performance, providing more reliable results.

According to Alter[7], flexibility rates for adolescents reach to a plateau and then drop again, which suggests that these are the best values and likely to be reduced, that is, further increasing the number of those who cannot reach feet. Studies mentioned or investigated the reduced flexibility with age [2,6] regarding gender, being higher in females[3,6], while in others, the difference was not significant[12,26]. However, in the present study, no significant difference was found between genders, corroborating the findings by Lamari et al.[12] in a Japanese community. Some factors such as narrow age group and ethnical group definition may have helped to get to these data.

Forléo et al.[26] studied an age group that included children and adolescents assessed by using the same criteria and parameters, what may have provided questionable results, once studies by many authors have already showed that joint range of motion is reduced with age and more quickly during childhood [2].

Body constitution is an additional factor that can differentiate in terms of flexibility, Alter[7] comments about connective tissues dehydration constitutes of adherences and cross links with increased calcium deposits. On the other hand, Guedes and Guedes[8] report that adolescents have an inverse relationship between muscular and bone tissue thicknesses to fat thickness, that is, a strong gain of muscle and bone mass with a concomitant reduction of fat mass gain. These data can explain, in part, the reduced flexibility with age and justify the results of the study in discussion, once they show that most of the adolescents do not touch fingers on feet in the TSA. This result helps to better understand this phenomenon suggesting that in age groups above adolescence, flexibility will be even lower, corroborating the results reported by Alaranta et al.[6].

Changes on body constitution occurring with age are associated to changes particularly on muscles, one of the major components of general motor capacity, which justifies the reduced joint range of motion with age. However, in the present study, gender did not cause bias to AFT quantification. It is possible that this result is associated to the various modifications experienced in this transition period by this age group. In this context, by considering that changes occur during adolescence in a short period of time, results of studies including representative samples of different age groups may be compromised. An exception to this is made to the study by Guedes and Guedes[8], which presented results by age groups.

Populational studies led authors to conclude that flexibility reduced with age [2,6], which was attributed by Malina and Bouchard[25] to the increased diameter of muscular fibers. However, children, adolescents and adults were included in the same study, which, according to the investigation by Lamari et al.[12] may have compromised the argument presented by the authors for the results associated to this topic.

The fact that the hyperflexion characteristic is a rare variable even among children, who are regarded as a population with greater joint ranges of motion in general [2,26], this feature helped on the study in discussion, once its incidence in adolescents was lower than in children, suggesting an even lower incidence in adults, as shown by literature regarding flexibility behavior with age.

Anthropometric measures achieved outstanding positions in explanations about AFT results in the present study, but correlations are not strong, showing the existence of a correlation between anthropometric data for both genders and trunk flexibility rates. Therefore, anthropometric measures reflect morphologic changes occurring during adolescence and these, in turn, on flexibility motor capacity. Nevertheless, studies by Grenier, Russel and Mcgill[21] did not find a correlation between AFT rates and anthropometric data when they assessed 72 subjects of both genders between 20 and 51 years of age. It is highlighted that the anthropometric variables in that study were different from those employed in the present study, did not include the same variables, making results discussion difficult in this circumstance. On the other hand, Guedes and Guedes[8] reported the implications of anthropometric measures associated to growth, to body constitution, and to flexibility motor performance, and they reported that teenager bodies may be further susceptible to the influence of genetic and environmental factors.

Feldman et al.[4] , when assessing individuals at peripubescent phase found no correlation between rates and adolescence, and that the anthropometric measures poorly influenced AFT factor regarding trunk-head height, body weight, span and height, considering previously mentioned exceptions. There are clear structural differences between genders regarding height and body weight, which are lower in females. However, in the present study, body weight differences between genders did not imply on differences in AFT variable pattern. In this context, this study managed to reinforce the findings by Feldman et al.[4] when they report that, in general, the anthropometric measures poorly influenced AFT, except for previously mentioned items.

As shown by Oliver[19], spinal motility will be affected by several factors, such as height and body weight. In the present study, it is concluded that the higher the girl, the lower the AFT. On the other hand, most of male adolescents did not present significant correlations. Upon these results, we disagree with the statements by Oliver[19], and generalizing his findings is not recommended. Still in the present study, both trunk-head height and body weight did not influence on AFT quantification. Thus, it is expected that the longer the LLLL, the lower the AFT, because distance to feet is bigger, and, the longer the UULL, the higher the AFT due to a reduction of the distance between UULL and feet. However, we found a subtle trend towards the fact that the longer the LLLL and UULL, the lower the flexibility. Thereby, it is possible that a longer UL, as a result of the ability to increase distance to feet, could reduce the possibility of reaching the thresholds of these rates. On the other hand, the same reasoning cannot be regarded as valid for UULL and span, although size does not imply on reducing the distance from reaching rates thresholds. This result suggests that, in general, higher values for anthropometric measures tend to lower flexibility rates.

Among the studies quantifying AFT by TSA, only one reported results comparable to this study's. Guedes and Guedes[8] assessed AFT in children and adolescents between 7 and 17 years old by TSA and found that, regarding age groups corresponding to the ones in the present study, those 16-year old teenagers reached 8.1cm (± 6.7cm) above feet in average, and those 17-year old teenagers reached 7.7cm (± 6.0cm). It is also important to highlight that, in the study by Guedes and Guedes[8] three attempts were made, and, for evaluation purposes, the best result was considered. This procedure must have led to different results from those obtained in this study, once the individual has probably been benefited by the warm-up, ultimately providing a better flexibility. On the other hand, no information was included regarding speed. Should they have used the fast speed resource, they would also provide better results.

Measurements performed at slow speed reduce the risk of trauma and suggest more reliable data if we consider the hypotheses of the benefits provided by fast movement. It was evident by the present study that the majority of adolescents cannot reach the full range of motion, even at fast speeds, where exactly half of this population cannot touch feet by anteriorly flexing the trunk.

In general, the studies did not provide quantitative data regarding AFT rates, a circumstance that made comparative analyses of this aspect difficult. Therefore, we suggest that further studies with adolescents after HSP are conducted, quantifying AFT rates.

CONCLUSIONS

There are evidences towards the fact that gender, anthropometric data and movement performance speed influence AFT rates by TSA. Higher flexibility rates were obtained when the test was conducted at a fast speed, and, among anthropometric measures, only height, span and limbs length showed a positive and significant correlation.

Most teenagers cannot touch hands fingers on feet by performing TSA, with 90% of them reaching 12 cm above feet. At fast speed, 10% of the less flexible adolescents reach 15 cm above feet, at most, and 10% of the most flexible ones reach at least about 8 cm below feet.

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