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REFERENCE VALUES FOR HAMSTRING AND QUADRICEPS STRENGTHS IN APPARENTLY HEALTHY YOUNG INDIVIDUALS

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Abstract
Background: This paper highlights an essential need for population-specific databases on muscle performance parameters due to the expected ethnic differences and other variability factors. In order to address the issue of the lack of these vital normative data in developing countries, the study reported here was meant to determine the reference values for hamstring and quadriceps strengths in apparently healthy young Nigerian individuals. Methods: A cross-sectional study recruited 194 apparently healthy participants aged 18-35 years. The participants were clustered into four age categories (<20 years; 21-25 years; 26-30 years and 31-35 years). Anthropometric measurements (weight, height and body mass index) were taken following the standard guidelines. A pocket balance and a cable tensiometer were used for hamstrings strength and quadriceps strength measurements, respectively. The Hamstring-Quadriceps (H/Q) Strength ratio was calculated. Descriptive statistics of the mean and the standard deviation, and the percentiles summarize the data collected. T-test inferential statistics, an ANOVA test, and the Pearson's correlation coefficient were applied in the analysis of the data. The alpha level was $p \leq 0.05$. Results: The mean hamstring and quadriceps strengths recorded were 25.83Kg and 44.18Kg, respectively. The mean hamstring and quadriceps strengths of the male participants were significantly ($p<0.05$) higher than those of the female participants. Also, the mean hamstring and quadriceps strengths differed significantly ($p<0.05$) across the age categories except for the H/Q ratio, which showed no significant difference ($p>0.05$). Conclusion: This study has provided reference values for hamstring and quadriceps strengths of apparently healthy young Nigerians.
Key words: *reference values, quadriceps and hamstring strength, young individuals*

Introduction

Reference values are significant clinical outcome values which facilitate evaluations and clinical decision-making by health care professionals in diagnostic procedures and interventions [1]. There is plenitude of studies on reference values for muscle strengths of the upper and lower extremities, with more emphasis on the upper extremity rather than the lower extremity [1, 2], which could be accounted for by two factors: a simpler procedure for the assessment of the upper extremity strength with the use of portable dynamometers [1], and the notion that handgrip strength measures could be a surrogate determiner for the lower extremity strength [2]. However, this trend has changed due to the increased awareness of the need for regional muscle strength evaluation. Another reason is the conflicting reports from studies which considered the upper extremity strength scores as surrogate indication for the lower extremity strength. A number of studies have suggested comparing a normal extremity with an abnormal side or with reference to a normative value in order to quantify the diminished function [3, 4], thus reaffirming the need for regional muscle strength evaluation.

Lower extremity muscle strength accounts for about 15% of all reference values of muscle strength [1]. Also, hamstring and quadriceps strengths seem to be the most researched parameters in lower extremity muscle strength assessments and rehabilitation [5]. Hence, restoring hamstring and quadriceps strengths are vital rehabilitation goals following injuries sustained in the lower extremity [6]. Similarly, the hamstring and quadriceps strengths ratio is a standard screening tool for the lower extremity injuries [5, 7]. Several methods are applied in assessments of hamstring and quadriceps strengths [5, 8, 9], yet, reference values for axial and appendicular muscle strengths evaluation in low-income countries are not available. Jaiyesimi [10] evaluated gender effects on hamstring and quadriceps strengths ratios in a Nigerian population with no documentation on reference values. Given the possibility of ethnic differences and other variability factors in muscle strength evaluation [1, 11], the dearth of studies on reference values for lower limbs in low-income countries [1], and the increase in sport participation among individuals aged 19 to 29 years [12], this study was designed to determine the reference values for hamstring and quadriceps strengths in apparently healthy young Nigerian individuals.

Materials and Methods

One hundred and ninety-four apparently healthy metropolitan dwellers of Ile-Ife, Osun State Nigeria, participated in this study. The study site was the research laboratory of the department of physiotherapy, Obafemi Awolowo University (OAU), Ile-Ife. The prospective subjects, both male and female, aged 18-35, were purposively recruited into the study from the city of Ile-Ife. The inclusion criterion was healthy physical appearance and proper fitness with no reported diseases, while exclusion criteria were any visible musculoskeletal lower limb impairments and reported conditions. The Research and Ethical committee of Obafemi Awolowo University Teaching Hospital Complex, Ile-Ife, gave ethical approval for this study. The participants signed informed consent forms. We derived the sample size (N) using the formula for estimating difference from zero of the correlation coefficient [13] as: N = [(Zα + Zβ) ÷ C] 2 + 3; where Zα= 1.96; Zβ= 0.842; C= 0.203. N= [(1.96 + 0.842)/0.203]2 + 3=194. A stadiometer (Seca, Prazision fur die Gesundheit, Germany) was used for the measurements of the height [14], and a weighing scale (Camry, BR9012) measured the weight [15]. A pocket balance (White House, UK) measured the subjects' hamstring strengths [16], while a baseline cable tensiometer (FEI-12-0411, Rehabmart) measured their quadriceps strengths [17].

Procedure: Evaluation of Quadriceps Strength

The subjects assumed a sitting position on a testing table with a backrest, maintaining a 1200 hip joint extension and 600 knee flexion as described by Richard and Currier [17]. A cable tensiometer stationed on the floor and attached to an ankle cuff recorded the peak isometric force (Kg) of the quadriceps. Verbal motivation with the word "pull" was used to ensure maximum isometric knee extension strength.

Evaluation of Hamstrings Strength

The subjects lay prone with their legs projecting beyond the edge of the testing table. A cuff was attached proximal to the ankle joint and hooked to the pocket balance, the base of which was attached to the testing table as described by Balogun and Onigbinde [18].
Restriction of compensatory movements during measurement involved the use of a strap to stabilize the subjects' hip joints. The participants were instructed to bend the knee at the command and pull the ankle towards the hips. The resulting maximum isometric force was recorded.

Data Analysis

The Statistical Package for Social Sciences version 17 was used to generate descriptive statistics of the mean and the standard deviation, and the data collected were summarized in percentages. Also, the inferential statistic of Analysis of Variance

(ANOVA) compared the variables across the age groups, while an independent t-test compared all the variables between male and female participants. The Pearson's product-moment correlation coefficient tested the relationship between the participants' physical characteristics and the reference values for hamstring and quadriceps strengths.

Results

The participants' demographic and anthropometric characteristics are as presented in Table 1. The mean age of the participants was 25.1 ±4. 44 years. Also, the mean height, weight and body mass index of the participants were 1.61±0.09 m, 67.68±13.3 Kg, and 26.15±3.57 Kg/m2, respectively. The male participants were taller (1.65 vs 1.57) and heavier (69.23 vs 65.88) than the females. The mean hamstring strength (MHS) and mean quadriceps strength (MQS) recorded for all the subjects were 25.83Kg and 44.18Kg respectively (Table 2). The males scored higher than the females in the mean (30.68 ± 6.46Kg vs 20.36 ± 4.30Kg), the 25th percentile (26.17 vs 17.127), the median (31.53 vs 19.20), the 75th percentile (36.17 vs 22.83), and the 95th percentile (41.01 vs 28.17) hamstring strength values (Table 2). Similarly, with reference to the quadriceps strength values, the males scored higher than the females in the mean (50.03 ± 5.91Kg vs 37.60 ± 6.70Kg), the 25th percentile (46.60 vs 32.73), the median (50.17 vs 37.63), the 75th percentile (54.47 vs 42.47), and the 95th percentile (57.93 vs 49.13) (Table 2).

Table 1. General characteristics of the participants

Variables	Gender	*X ± SD*	*t*-value	*p*-value
Age (years)		25.15 ± 4.44		
Height (m)		1.61 ± 0.09		
Weight (Kg)		67.7±13.33		
BMI (Kg/m²)		26.2±3.57		
		Gender		
Height	Male	1.65	5.07	0.00*
	Female	1.57		
Weight	Male	69.23	1.45	0.15
	Female	65.88		

Table 2. Reference values for Hamstring Strengths (HS) and Quadriceps Strengths (QS)

Variable	Minimum	25th	Median	X ± SD	75th	95th	Maximum
All Participants							
HS	14.33	19.17	24.55	25.83 ±7.57	32.53	38.60	44.70
QS	22.80	37.40	45.40	44.18 ± 8.83	52.32	57.54	60.10
HS							
Male	17.50	26.17	31.53	30.68 ± 6.46	36.17	41.01	44.70
Female	14.33	17.27	19.20	20.36 ± 4.30	22.83	28.17	35.53
QS							
Male	35.30	46.60	50.17	50.03 ± 5.91	54.47	57.93	60.10
Female	22.80	32.73	37.63	37.60 ± 6.70	42.47	49.13	56.63
HS <20 years19-20							
Male	17.50	18.95	23.60	22.86 ± 4.26	24.60	-	31.53
Female	14.33	14.37	15.47	16.88 ± 3.08	19.07	-	22.30
Male & Female	14.33	15.98	19.13	20.24 ± 4.78	24.18	-	31.53
HS 21-25 years							
Male	18.13	25.14	27.42	29.01 ± 5.57	33.17	39.55	43.60
Female	14.73	16.61	17.65	19.17 ± 3.91	22.07	29.12	30.57
Male & Female	14.73	18.15	24.37	24.79 ± 6.93	30.59	36.35	43.60
HS 26-30 years							
Male	26.47	30.57	34.80	34.24 ± 4.47	37.18	-	43.57
Female	16.53	18.57	22.40	22.57 ± 4.42	25.46	33.74	35.53

Male & Female	16.53	21.63	26.77	27.41 ± 7.28	34.68	38.75	43.57
HS 31-35 years							
Male	25.33	32.88	36.40	35.51 ± 5.28	38.85	-	44.70
Female	16.40	17.77	20.25	20.36 ± 2.78	22.64	-	24.37
Male & Female	16.40	21.83	30.60	29.74 ± 8.73	36.65	44.16	44.70
QS <20 years							
Male	36.67	37.05	42.33	41.81 ± 4.34	45.53	-	47.37
Female	22.80	24.70	28.63	29.59 ± 6.20	32.73	-	41.13
Male & Female	22.80	29.29	37.05	36.46 ± 8.04	44.66	-	47.37
QS 21-25 years							
Male	35.30	46.43	48.43	48.10 ± 4.63	50.55	56.57	58.23
Female	26.53	30.63	36.80	36.59 ± 6.15	41.95	49.13	50.33
Male & Female	26.53	37.17	45.75	43.17 ± 7.81	48.84	54.53	58.23
QS 26-30 years							
Male	49.73	51.98	54.47	54.74 ± 3.16	57.55	-	60.10
Female	29.67	36.18	41.83	40.36 ± 6.13	43.36	54.92	56.63
Male & Female	29.67	39.33	45.37	46.32 ± 8.78	54.37	58.54	60.10
QS 31-35 years							
Male	47.40	53.18	54.73	54.29 ± 3.25	57.05	-	57.57
Female	33.47	35.58	39.08	39.37 ± 4.42	42.69	-	46.60
Male & Female	33.47	41.33	53.00	48.60 ± 8.26	56.15	57.56	57.57

It was also noted that the hamstring strengths values increase with age in the period between 21 and 30, whereas the quadriceps strengths values increase with age between 21 and 35. The mean hamstring to quadriceps (H/Q) strength ratio was 0.58 ± 0.09 for all the participants (Table 3). A significant ($p<0.05$) gender difference was observed in hamstring strength, quadriceps strength, and the H/Q strength ratio for all the participants (Table 4). The MQS and MHS differed significantly across the age groups except for the H/Q ratio, which showed no significant difference ($p=0.25$) (Table 5). Also, age has a significant positive correlation with the MHS, MQS, and mean H/Q strength ratio respectively (Table 6). Height has significant positive correlation with the MHS and MQS (Table 6). Weight correlated with quadriceps strength. Also, a significant positive correlation resulted between hamstring strength and quadriceps strength (Table 6).

Table 3. Reference values for Hamstring Quadriceps Strength Ratio

Variable	Minimum	25th	Median	X ± SD	75th	95th	Maximum
All Participants							
Male & Female	0.41	0.52	0.55	0.58 ± 0.09	0.64	0.71	0.95
Male	0.46	0.53	0.62	0.61 ± 0.09	0.67	0.75	0.95
Female	0.41	0.50	0.53	0.54 ± 0.07	0.58	0.65	0.86
<20 years19-20							
Male & Female	0.47	0.51	0.54	0.56 ± 0.06	0.62	-	0.69
Male	0.47	0.49	0.52	0.54 ± 0.08	0.60	-	0.69
Female	0.50	0.54	0.58	0.57 ±0.04	0.62	-	0.63
21-25 years							
Male & Female	0.41	0.51	0.55	0.57 ± 0.10	0.62	0.72	0.95
Male	0.46	0.53	0.59	0.60 ± 0.11	0.65	0.92	0.95
Female	0.41	0.49	0.52	0.52 ± 0.05	0.56	0.62	0.62
26-30 years							

Male & Female	0.43	0.52	0.58	0.59 ± 0.09	0.65	0.72	0.86
Male	0.49	0.57	0.64	0.62 ± 0.07	0.67	-	0.72
Female	0.43	0.51	0.53	0.56 ± 0.09	0.61	0.82	0.86
31-35 years							
Male & Female	0.46	0.52	0.60	0.60 ± 0.09	0.68	0.78	0.79
Male	0.52	0.60	0.68	0.65 ± 0.08	0.69	-	0.79
Female	0.46	0.48	0.52	0.52 ± 0.04	0.53	-	0.60

Key: HQSRatio=Hamstring Quadricep Strength Ratio.

Table 4. Independent t-test comparison of the general characteristics with Hamstring Strength, Quadriceps Strength, and Hamstring- Quadriceps Strength Ratio

Variables	Gender	X ± SD	t-cal	p-value
Hamstring Strength (Kg)	Male	30.49 ± 6.60	10.26	0.00*
	Female	20.41 ± 4.31		
Quadriceps Strength (Kg)	Male	49.86 ± 6.02	11.11	0.00*
	Female	37.59 ± 6.75		
Hamstring-Quadriceps Ratio	Male	60.8 ± 9.45	4.31	0.00*
	Female	4.49 ± 7.06		

* indicate significant difference at $p<0.05$

Table 5. ANOVA for effects of age on Quadriceps Strength, Hamstring Muscle Strengths, and Hamstring-Quadriceps Strength Ratio

	Mean Muscle Strength (Kg)					
Variables	< 20 years X ± SD	21- 25 years X ± SD	26-30 years X ± SD	31-35 years X ± SD	F-ratio	p-value
MHS (Kg)	20.25	25.54	27.41	29.74	7.88	0.00
MQS (Kg)	36.91	44.05	46.60	48.60	9.50	0.00
H/Q (Kg)	55.00	57.50	58.80	60.00	1.39	0.25

Key: MQS=Mean Quadriceps Strength; MHS=Mean Hamstring Strength; H/Q=Hamstring-Quadriceps ratio.

Table 6. Pearson's product-moment correlation analysis of the relationship between the general characteristics (age, height, weight, BMI) and each of mean hamstrings, mean quadriceps, and mean hamstring/quadriceps strengths ratio

Variable		Age	Height	Weight	BMI	MHS	MQS	MHQSRatio
Age	*r*	-	0.196*	0.251**	0.218*	0.374**	0.386**	0.178*
	p		0.023	0.003	0.011	0.000	0.000	0.039
Height	*r*		-	0.667**	0.072	0.321**	0.329**	0.155
	p			0.000	0.409	0.000	0.000	0.073
Weight	*r*			-	0.689**	0.139	0.188*	0.003
	p				0.000	0.108	0.030	0.977
BMI	*r*				-	-0.089	-0.007	-0.161
	p					0.306	0.938	0.064
MHS	*r*					-	0.871**	0.736**
	p						0.000	0.000
MQS	*r*						-	0.321**
	p							0.000

* Correlation is significant at the 0.05 level (2-tailed).

** Correlation is significant at the 0.01 level (2-tailed).

KEY: BMI= Body Mass Index; MHS= Mean Hamstring Strength; MQS= Mean Quadriceps Strength; MHQSRatio= Mean Hamstring Quadriceps Strength Ratio.

Discussion

This study was meant to determine the reference values for hamstring and quadriceps strengths in apparently healthy young individuals in a Nigerian population. Reference values are prerequisite clinical outcome values in the hand of a proficient clinician for diagnosis and interventions. Anecdotal evidence revealed the use of normative scores of muscle strengths studied in one population among clinicians in another population. As developed countries are bracing up to meet the deficiency of established reference values for muscle strengths in their populations, Benfica [1] reported a greater need for the upper and lower extremities strengths reference values for low-income countries. Jaiyesimi [10] evaluated hamstring and quadriceps ratios for a Nigerian population with a focus on the age and gender effects rather than establishing reference values. This present study is the first to establish the mean and percentile data on the hamstring and quadriceps strengths in an apparently healthy young Nigerian population. Also, this study has established the incremental five years age difference in reference values in apparently young Nigerians aged from twenty to thirty-five years old. The mean quadriceps and hamstring strengths obtained in this study are comparable to those reported by Jaiyesimi [10] within the same age categories. Also, the mean hamstring values obtained in this study are comparable to those reported by Pasco [2] in the same age category in Australia, yet higher than the scores reported by Benfica [1] for the same age categories. Similarly, the mean hamstring and quadriceps strength reference values obtained in this study are higher than those reported by Meldrum [19] and Danneskiold-Samsøe [20]. However, the 25th percentile values for hamstring and quadricep strengths obtained in this study are comparable to the mean values reported by Meldrum [19] and Danneskiold-Samsøe [20]. Again, the mean quadriceps strength obtained in this study is lower than that reported by Narumi [21] for the same age categories in a Japanese population. It is worth noting that the 95th percentile for quadriceps strength recorded in the subjects in this study is comparable to the mean values obtained by Narumi [21] in the same age categories. This variability in reference values for quadriceps and hamstring muscle strengths among different populations has been noted in previous studies and included ethnicity, the study population, the range of motion, and the velocity of movement in the generation of quadriceps-and-hamstring force [1, 11]. Hence, while the reference or normative values are convenient for muscle strength assessment, it is imperative to assess muscle strength for every individual taking into account any conditions of the lower extremities which involve the sparing of one limb caused by the disease.

Furthermore, this study has found a significant difference in the mean values of the quadriceps and hamstring muscle strength in 5-year incremental age intervals. The mean values were progressive from the age of less than twenty to thirty-five with the most significant change recorded for the age group between less than twenty and twenty-five. This finding is consistent with previous studies which reported an increase in mean hamstring and quadriceps strengths in subjects from twenty years of age up to a certain level before declining [20, 21]. Our findings of the greatest increase in the mean quadriceps and hamstring muscle strength between the age of twenty and twenty-five agrees with the data reported by Danneskiold-Samsøe [20], and Asmussen and Heebøll-Nielsen [22]. However, the hamstring-quadriceps strength ratio showed no significant difference between the five-year incremental age intervals. This finding could probably be attributed to the decline in incremental muscle strength in quadriceps and hamstrings across the age intervals.

Again, this study attests gender differences in reference values for mean hamstring and quadriceps strength. The scores recorded for male subjects were significantly higher than those obtained by the females in all measurements of hamstring and quadriceps strengths. Also, the hamstring-quadriceps ratios were significantly higher in the male subjects. These findings are in line with the previous studies which reported that healthy men demonstrate higher hamstring and quadriceps strength than women [10, 21]. However, this finding is in contrast to the report by Meldrum [19] who found higher reference values in mean hamstring and quadriceps strengths for women. Also, Meldrum [19] asserts that anthropometric measures of height and weight could impact gender differences in muscle strengths, which corroborates with the data recorded in this study: the male participants were taller and heavier than the females. Similarly, this study has found that the participants' heights had significant positive correlation with hamstring and quadriceps strengths, while weight correlated with quadriceps strength only. As such, this finding is consistent with the reports by Hogrel [23] and Mckay [24], who asserted that height is a significant determinant of muscle strength. Also, the positive correlation of weight with quadriceps strength in this study corroborates the data reported by Miyatake [25]. Furthermore, this study concludes that the correlation between the body mass index and hamstring-and-quadriceps strengths were not significant. This finding further supports the claim by Hogrel [23] that height and the lean body mass rather than weight enhance the parameter of muscular strength. However, this finding is incongruent with the data reported in previous studies [24, 26] which asserted a significant correlation between muscle strength and the body mass index.

Finally, this study has found a positive correlation between hamstring strength and quadriceps strength, which is not unexpected because both hamstrings and quadriceps are the primary muscles of the knee joint working in synchrony to maintain knee stability, flexibility, and prevent injuries [27]. In performing their roles, one acts as the agonist while the other plays the role of an antagonist. However, the reported hamstring strength ranges from 50% to 80% of the quadriceps strength in a healthy individual [28, 29]. Our findings regarding the hamstring-quadriceps-strength ratio show that the average hamstring strength in a healthy young Nigerian aged 18 to 25 is 58% lower than the corresponding quadriceps strength in both genders. With reference to gender-specific results, the average hamstring strength in males is 61% lower than the corresponding quadriceps strength, whereas in females the average hamstring strength is 54% lower than quadriceps strength. Although the significance of the hamstring-quadriceps ratio is highly debatable [28], the ratio provides an estimate of comparative strength of these two muscles; it also may be an indicator for several biomechanical variables such as the flexibility of the hip and knee joints, joint stiffness, and morphological adaptations.

Although the scope of this study is the reference values for young Nigerians, it should be noted that its findings may not be useful for individuals under the age of 18 and over 35. Also, since the subjects reported to be healthy, the reference values may not apply to those affected by medical conditions. Yet, this study indicates knowledge gaps of reference values which should inspire further research in both apparently healthy and diseased individuals.

Conclusion

This study was intended to provide the reference values for quadriceps and hamstring strengths in apparently healthy young Nigerians. The reference values for the mean strengths of quadriceps and hamstring obtained in this study are confined to the population studied, and the anthropometric measures of height and weight as well as the demographic variables of age and gender affect muscle strength. The reference values obtained in this study can serve as a baseline database in the rehabilitation of lower limbs in young Nigerians and also serve as a template for further research. Also, strength and conditioning specialists may find the outcome of this study very useful for the assessment of strength in the young population of Nigerians, especially in male and female athletes who take part in football and athletic competitions

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