ORIGINAL ARTICLE

CORRELATION OF UPPER AND LOWER LIMB STRENGTH WITH BODY MASS INDEX AND WAIST TO HIP RATIO IN YOUNG ADULTS

Tehreem Baig, Hafiza Sana Ishfaq, Yasha Sajjad, Khansa Nasir, Zunaira Talib, Syeda Rida Batool

School of Allied Health Sciences, CMH Lahore Medical College and Institute of Dentistry, Lahore, Pakistan

Background: Body mass index (BMI) and waist-to-hip ratio (WHR) indicate body fat distribution, which can reduce muscle strength. The objective of this study was to determine the correlation of upper limb strength and lower limb strength with BMI and WHR in young adults. **Methods:** This cross-sectional study was conducted on a total of 105 young healthy adults (18–25 years) recruited from a medical college with convenience sampling. Span of study was six months from 1 May 2023 after approval from the Institutional Ethical Review Board. Manual Muscle Testing (MMT) was used to measure the strength of upper extremity and for lower limb strength 30 seconds sit to stand test (STS) and 20 m shuttle run test (SRT) were utilized. Pearson correlation test was run to find correlations. **Results:** WHR and BMI had a statistically significant but mild correlation (p=0.01, r=0.26). BMI was significantly correlated with MMT of Finger flexors and 30 sec-STS (p<0.05). BMI with upper limb strength and lower limb strength was not found to be correlated (p>0.05). WHR had no statistically significant correlation with strength of shoulder abductors, biceps and finger flexors, 20 m shuttle run test and 30 sec sit-to-stand test. **Conclusion:** Positive correlation was present between BMI and WHR. Strength of finger flexors, shoulder abductors and bicep muscles were significantly correlated with lower limb strength. Body Mass Index and Waist to Hip Ratio decreased finger flexors strength and 30 seconds sit to stand repetitions.

Keywords: Upper extremity, lower extremity, muscle strength, BMI, WHR, Young Adults

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INTRODUCTION

Strength is 'the maximum force that a person can apply against resistance'. The upper limb strength increases by physical exercises and helps in the execution of daily tasks and aids in a speedy recovery.[1] Muscle strength shouldn't be diminished because it directly affects functional capacity and activities of daily living (ADL) and serves as a protective factor against cardiovascular diseases, the development of lesions, osteo-articular lesions, sarcopenia, depression, anxiety and pulmonary conditions as well.[2]

In the Indian population, adults with more than 20 years of age have loss in muscle strength prevalence rates from 2.3% to 14.6%.[3] Shoulder flexor strength was found to be less than normal in overall more than 50% of young Pakistani women.[4] Upper limb strength is usually assessed by hand grip strength, portable dynamometer and Manual Muscle Testing (MMT).[5] A clinical strength evaluation exam called manual muscle testing (MMT) can be used as a subjective means of grading muscles into six categories, from grade 5 to grade 0. This method is more reliable, diverse and specific according to the muscles involved rather than going for hand dynamometer like tests that can only measure some muscles.[4,5]

Lower limb strength is the ability of the body to insert a maximum productive force opposing an object of an external environment.[6] Lower limb muscle strength is essential for mobility, locomotion, agility, endurance and ADLs, and it is the pivotal for retaining functional independence in younger and elderly age. Falls, fractures, co-morbidities, and other causes of mortality are direct causes of lower muscular weaknesses or *vice versa*.[6,7] Lower limb strength can be measured by different tests like time up and go test (TUG), 6 minute walk test, stair climb power test. But the most widely used test to measure lower limb strength is 20 minutes shuttle run test (20 m SRT) and sit to stand test (STS) in 30 seconds.[8]

Obesity is referred to as excessive build-up of body fat with many organ-specific effects. Words like abdominal obesity, abdominal fat percentage, and obesity prediction are used interchangeably with obesity.[9] The waist-to-hip ratio (WHR) is the straightforward measurement that has previously been employed in epidemiological investigations.[10] Body Mass Index (BMI) is used to determine whether a person's weight corresponds to height.[11]

Hips and waist need to be in proportion. If the waist is wider than the hips, then this is a sign of 'intra-abdominal obesity'. People with remarkable abdominal obesity have waist-to-hip circumference ratio of >0.8 for women and >1.0 for men, usually have higher total cholesterol levels, according to the National Institute of Diabetes and Digestive and Kidney Diseases (NIDDK). Cardiac diseases and type 2 diabetes mellitus (T2DM) are non-communicable diseases that result directly from excess of body fat.[12]

It has been observed that 6–11 years old young school children with raised BMI have decreased scores on shuttle run test and agility related drills as compared to children with normal BMI.[13] People with raised BMI, disturbed WHR and obesity are more prone towards developing T2DM with dyslipidemia, hypertension, osteoarthritis, sleep apnoea, gallbladder disease, stroke and infertility. At least 10 cancers, including endometrial, breast and colon cancers, tend to afflict people with obesity. Amongst people who have never smoked, weight problems are associated with a 51% rise in mortality in comparison with human beings who have normal weight charts.[14]

Moreover, in 60–80 years old, grip strength by using manual dynamometer have shown to be decreased in people with higher BMI.[15] In another study, it has been observed that raised WHR, decreased grip strength and being obese were positively correlated with each other in 48–92 years old adults.[16]

Previous studies have explored the correlation either between lower limb or upper limb strength and BMI, as well as obesity-related parameters, in adolescents, children, and older adults. Grip strength has been used as the measure of upper limb strength, which does not assess specific upper extremity muscles in relation to BMI and WHR. The objective of this study was to determine the correlation of upper limb and lower limb strength with BMI and WHR in young adults. In Pakistan, the youth population (ages 15–24 year) constitutes about 64%, making this study particularly relevant.

MATERIAL AND METHODS

This was a cross-sectional study with non-probability convenience sampling, conducted at a Lahore based medical college for six months, from 1 May 2023, with permission of the Institutional Ethical Board. It recruited both male and female students aged 18–25 years without any underlying pathology, and excluded subjects with recent fractures in the last 3 months, and any diagnosed psychological and metabolic disorders.

Study included 105 participants calculated through the formula: $n=[z^2p(1-p)]/d^2$, where n=sample size, z=for 95% confidence interval (1.96), p=prevalence (6%)[17], d=sample size constant (0.05). Subjects were recruited through personal interviews after informed written consent. Manual Muscle Testing (MMT)[18] for upper limb strength was utilized for finger flexors, shoulder abductors, elbow flexors, elbow extensors, wrist extensors and biceps muscles with application of manual resistance against the movement specific to specific muscles, provided by investigator. They were graded from 0 to 5, where 0 indicated no movements or contractions against the resistance and 5 showed full completion of range of motion against the maximum resistance.

Participants were asked to run as fast as possible for 20 minutes, back and forth between two points, 9 meters apart. This back-and-forth movement between two points represented one shuttle. Number of shuttles in a set time represented strength of lower limb.[8]

BMI of the participants was calculated. BMI above 25 Kg/m^2 was considered overweight, and more than 30 Kg/m^2 as obese.[10] Waist to hip ratio[9] was calculated. A threshold score of 0.95 in males and 0.80 in females was applied.[19]

Participants performed a proper sit-to-stand on a standard 17 inches high chair with crossed arms across their chests and to sit up properly in the centre of the chair with feet shoulder width apart and placed on the ground. While performing a stand-up, they were asked to straight up their trunks fully.[20] Timer of 30 seconds was set on the stopwatch. A cut-off value for the fit person was more than 20 sit to stand.[21]

SPSS-25 was used for data entry and analysis. Pearson correlation was used, and $p \leq 0.05$ was considered significant.

Figure-1: Position for sit-to-stand test

RESULTS

Upper limb strength was correlated with lower limb strength significantly (p<0.05). The mean age was 22.62±1.92 years in males and it was 21.85±1.62 years in females. BMI was 24.01±3.72 years in males and 21.07±3.32 in females. Waist to hip ratio was 0.84±0.08 in males and 0.78±0.05 in females. (Table-1).

BMI was significantly and correlated with waist to hip ratio, 30 sec sit-to-stand test and strength of finger flexors (p<0.05). BMI was not correlated with strength of biceps, shoulder abductors, and 20 min shuttle run test. (Table-2).

Waist to hip ratio was weakly correlated with BMI (p=0.01, r=0.26). Waist to hip ratio has not shown any correlation with strength of shoulder abductors (p=0.43), bicep muscles (p=0.40) and finger flexors (p=0.23), 20 m shuttle run test (p=0.09) and 30 sec sit to stand test (p=0.15) respectively. (Table-3).

Table-1: Clinical and descriptive statistics

Variables	Mean±SD	Min	Max
Age of male students (Years)	22.62±1.92	19	25
Age of female students (Years)	21.85±1.62	18	25
BMI of male students (Kg/m^2)	24.01±3.72	18.50	30.17
BMI of female students (Kg/m^2)	21.07±3.32	15.78	33.47
Waist/hip ratio (male)	0.84±0.08	0.69	0.95
Waist/hip ratio (female)	0.78±0.05	0.64	0.89
MMT-bicep muscles (ULS*)	4.86±0.35	4.00	5.00
MMT-shoulder abductor (ULS)	4.86±0.35	4.00	5.00
MMT-finger flexors (ULS)	4.85±0.36	4.00	5.00
20 min Shuttle Run (LLS*)	6.60±1.35	4.00	10.00
30 Sec Sit to Stand test (LLS)	15.95±2.87	10.00	24.00

*ULS: Upper Limb Strength; *LLS: Lower Limb Strength.

Table-2: Pearson correlation of BMI with WHR, ULS and LLS (n=105)

Test	*r*	*p*
Waist/hip ratio	0.26	**0.01**
Strength-bicep muscles	0.19	0.07
Strength-shoulder abductors	0.18	0.07
Strength of finger flexors	0.20	**0.05**
20 min Shuttle Run test	-0.16	0.11
30 Sec Sit to Stand test	0.23	**0.02**

Table-3: Pearson correlation of WHR with ULS and LLS (n=105)

Test	*r*	*p*
MMT of bicep muscles (ULS)	0.09	0.40
MMT of shoulder abductor (ULS)	0.08	0.43
MMT of finger flexors (ULS)	0.12	0.23
20 min Shuttle Run test (LLS)	-0.17	0.09
30 Sec Sit to Stand test (LLS)	0.15	0.15

DISCUSSION

A statistically significant association between BMI and waist to hip ratio was identified in the current investigation. BMI has shown correlations with upper limb strength (ULS) and lower limb strength (LLS) in cases of 30 sec STS and strength of finger flexors only. But WHR has not shown any association with ULS and LLS. It was established that strength of finger flexors, shoulder abductors and bicep muscles were significantly correlated with lower limb strength. It should be kept in mind that the average WHR for present study was recorded at 0.78±0.05, i.e., lower than the set cut-off value of 0.80 for females and 0.95 for males.

Da Silva TL *et al* conducted a study on the association of sarcopenia and muscle strength with obesity in young to middle-aged adults. The study utilized hand grip strength to assess upper extremity strength, dual-energy X-ray absorptiometry for body composition, and the five times sit-to-stand test to evaluate lower extremity muscles. The results showed a negative association between BMI, hand grip strength, and walking speeds, even in young adults.[22] Current study revealed that BMI also had negative associations with finger flexor strength and the 30-second sit-to-stand test. In contrast, no associations were found between BMI and other upper limb muscles or the 20-minute shuttle run test. The decreased muscle strength, especially in hand muscles, may be attributed to the accumulation of intermuscular and intramuscular fat, which leads to muscle mass catabolism and the degradation of type-II muscle fibres. While some tests showed significant correlations, others, such as the 20-minute walk test and manual muscle testing (MMT) of shoulder abductors and biceps, did not yield statistically significant results. However, overall decreases in values were noted with increasing BMI, although these decreases may not always be statistically measurable. Another possible explanation is that in younger age groups, certain muscle groups, such as the quadriceps, hamstrings, and wrist muscles, are more negatively affected by increasing BMI and fat deposition. Further research is needed to determine which muscle groups in specific age groups are most affected by fat accumulation.

An Indian study that recruited young adults to investigate the association of hand grip strength with BMI and body fat distribution showed that BMI was not associated with hand grip strength. They measured body fat using a bioelectric handheld device and found a negative association between body fat and hand grip strength. It should be noted that they used these simple measures to represent full-body strength and body fat distribution, but they did not account for other muscle groups or different fat distribution parameters. The current study found no correlation between BMI and other upper limb muscles, with only a mild association observed with finger flexors. In contrast, the current study also found no correlation between waist-to-hip ratio—an indicator of abdominal obesity—and upper and lower limb muscle strength. This difference might be due to low fat distribution in some areas and high fat distribution in others. Coincidentally, the muscles targeted in the current study may not have had significant fat accumulation to influence their

performance. However, there is a need to focus specifically on the performance of hip and spinal muscles in relation to waist-to-hip ratios.[23]

A study conducted by Niken Ayu Dewi *et al*. aimed to determine whether waist-to-hip ratio is related to 60-meter running speed. That cross-sectional study examined waist, hip, and leg lengths in addition to 60-meter running speed. The Pearson correlation test was used to assess the relationship between waist-to-hip ratio and 60-meter running speed. The results revealed a significant negative association (r= -0.515), indicating a moderate correlation between waist-to-hip ratio and 60-meter running speed (p<0.05).[24] Inconsistent with that study, the current research shows no correlation between waist-to-hip ratio and the 20-meter shuttle run test (p>0.05) and a further absence of any correlation with the 30-second sit-to-stand test (p>0.05) was also recorded. It is likely that fat deposition and increased abdominal obesity affects muscular endurance, which kicks in during longer periods of activity such as 60 meter running, more than the peak muscular force generation that is measured by short duration tests such as one repetition maximum and 30-second sit to stand. In sustained efforts, when continuous energy and oxygen is needed, cardio-respiratory fitness is an integral factor to provide that but in people with higher fat accumulations, this is hampered greatly, hence influencing endurance more as compared to muscular strengths.[25]

Another study by Gotmare N *et al*, suggested that sitting rising test is strongly correlated with 30 second sit-to-stand test in young adults. Significant differences were found between sitting rising test and BMI and no correlation was found between sitting rising test and waist to hip ratio.[26] This study's findings are similar to present study's findings that also found no correlation between waist to hip ratio and 30 second sit to stand test, which is a milder version of sitting rising test as it involves mid segments rather than asking participants to rise from lower points, i.e., floor. This again reinforces the concept that intramuscular fat changes the stiffness levels and architectural properties of muscle and it can be the main factor for decreasing strength in particular muscles that have more intramuscular fat depositions.[27,28] This explains that overall deposition of muscle across the belly can influence cardio-respiratory fitness that translates in the form of reduced muscular endurances.[25]

There are a number of limitations of this study such as small sample size and participants recruited from one centre only. It remains unclear how other muscle groups, such as hip muscles and spinal musculature, might be affected by increased body fat over time. Waist to hip ratio and BMI are simple measures of fat deposition that cannot account for intramuscular fat deposition. It is important to observe the influence of fat deposition on overall contractile properties of muscles by using electromyography and ultrasonography to get a clear picture of identified correlations in this study. The study did not examine the impact of body fat on tasks requiring sustained effort. It is recommended for future researchers to investigate the impact of different parameters of obesity using advanced equipment for fat deposition on body strengths across the young people with obesity and other underlying conditions such as diabetes and hypertension at different time frames. Moreover, longitudinal studies are advised to gauge changes in muscle strength, endurance and physical functions over time with increased intramuscular fat build-up at different attachment points of muscles.

CONCLUSION

BMI was negatively associated with strength of finger flexors and 30 second sit-to-stand variable of lower muscle strength. BMI has no correlation with the strengths of biceps and shoulder abductors. Waist to hip ratio has no correlation with upper limb strength and lower limb strength.

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Address for Correspondence:

Dr Yasha Sajjad, Department of Physical Therapy, School of Allied Health Sciences, CMH Lahore Medical College and Institute of Dentistry, (NUMS), Lahore, Pakistan. **Cell:** +92-308-4639494

Email: yasha_sajjad@cmhlahore.edu.pk

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YS: Analysis and interpretation of the data, Critical review of manuscript, Final approval and guarantor of the article
KN: Data collection and assembly, literature search, drafting of manuscript
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SRB: Drafting of article, data collection

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