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COMPARATIVE STUDY OF BOTTOM GEAR AND TOP GEAR MUSCLES BETWEEN SPORTSPERSONS AND SEDENTARY LIFESTYLE PERSONS

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ABSTRACT:
Background: The triceps surae complex is a complex of gastrocnemius and soleus muscles and is of fundamental importance in locomotion, postural control and athletic performance. The gastrocnemius muscle is mainly involved in quick and powerful movement and the soleus is mostly involved in long-term postural and endurance tasks. These muscles can vary in structural adaptations depending on the usual physical activity and training conditions.
Objective: To compare the thickness of gastrocnemius and soleus muscles, to determine the relative contribution of the gastrocnemius muscle to the triceps surae, and the length of the tendo calcaneus in sportspersons and sedentary persons.
Methods: A case study was done on 100 respondents (50 sportspersons and 50 sedentary persons) sampled out of Alluri Sitarama Raju Academy of Medical Sciences, Eluru, during the academic year 2024-2025. The participants were divided into groups-based sex and paired by height (girls: 150 cm; boys: 165 cm). The sportspersons had at least five years of organized football or basketball trainees. The thickness of gastrocnemius, soleus and length of tendo calcaneus were measured by ultrasound imaging. The measurements were taken in a standardized prone position condition with the ankle in 90º and the average of the three measurements is taken. Data were analyzed using an independent t-test with statistical significance set at $p \leq 0.05$.
Results: Gastrocnemius muscle thickness was significantly greater in sportspersons compared to sedentary individuals in both sexes ($p \leq 0.05$). Among females, gastrocnemius thickness measured 1.32 cm in sportspersons versus 0.94 cm in sedentary individuals. Among males, the values were 1.33 cm and 0.94 cm, respectively. The proportional contribution of gastrocnemius thickness to soleus thickness was also higher among sportspersons (40.12 vs. 28.57 in females and 36.14 vs. 25.06 in males). No significant differences were observed in soleus thickness and tendo calcaneus length.
Conclusion: Regular athletic training appears to promote selective hypertrophy of the gastrocnemius muscle while preserving the structural characteristics of the soleus muscle and tendo calcaneus. These findings support the concept of activity-specific adaptation within the triceps surae and highlight the usefulness of ultrasonography in evaluating training-related musculoskeletal changes.

KEYWORDS: Gastrocnemius; Soleus; Triceps surae; Ultrasound; Muscle thickness; Athletic training.

INTRODUCTION

The triceps surae muscle group, consisting of the gastrocnemius and soleus muscles, plays a fundamental role in locomotion, posture maintenance, balance, and athletic performance. Together with the tendocalcaneus (Achilles tendon), these structures contribute significantly to plantar flexion of the ankle joint and efficient transfer of muscular forces during walking, running, and jumping activities (1,2). Morphology and architecture of skeletal muscles play a critical role in defining the force generating capacity, functional performance, and the adaptation to physical training (2).

The pattern of muscle fibers in relation to the force generating axis is known as muscle architecture and involves muscle-thickness, fascicle-length, and pennation-angle parameters. These attributes affect muscle power, strength and work efficiency (3). The training of resistance and endurance has been demonstrated to cause considerable changes in the muscle structure, leading to hypertrophy and improvement of functional capacity (4,5). In the same manner, repetitive mechanical loading leads to morphological and mechanical property changes in tendons that improve the transmission of force and sport performance (8,9).

Ultrasonography has become an acceptable, non-invasive, and affordable imaging modality to assess skeletal muscle morphology and tendon characteristics. It can give real time visualization of muscle thickness and tendon sizes with high reliability and reproducibility (6,7,10). Due to its ease of use and safety, ultrasonography has gained popularity in sports medicine and rehabilitation and musculoskeletal studies.

Past studies have established a high level of variation in muscle morphology of physically active people and sedentary people. The growing of muscle, improvement of muscle structure, and the enhancement of tendon characteristics are linked to athletic training when compared to populations that are untrained (4,5,8). It has also been reported that there are region-specific differences in Achilles tendon morphology between runners and non-runners with the suggestion that the habitual physical activity affects both tendinous and muscular adaptations (12).

Recent ultrasound researches has also revealed sport-specific changes in gastrocnemius muscle structure and have validated the applicability of ultrasonography in measuring soleus muscle morphology and pathology (14-16). Also, dynamic alterations in the thickness of plantar-flexor muscles during walking and running are reported, as well as the functional significance of gastrocnemius-soleus complex in human movement (17). Nevertheless, there is a dearth of information comparing gastrocnemius, soleus, and tendocalcaneus morphology in comparison to athletes and non-athletes using ultrasonographic measurements.

Thus, the purpose of the current research was to compare the thickness of gastrocnemius muscle and soleus muscle and the length of tendocalcaneus in sportspersons and sedentary people with the help of ultrasonography. The results can be of great value to the musculoskeletal changes that occur as a result of training and can be used in the comprehension of the lower limb muscle morphology in physically active groups.

Objectives

- To determine the difference in ultrasonographic thickness of gastrocnemius and soleus muscles in sportspersons and inactive people.
- To establish the proportional changes of gastrocnemius muscle thickness compared with soleus in both groups.
- To determine the differences in the tendo calcaneus (Achilles tendon) length between sportspersons and inactive people.
- To assess the effect of habitual sports training on morphometric change of the gastrosoleus complex.

MATERIALS AND METHODS

Study Design

Cross-sectional observational study.

Study Setting and Population

The research was carried out in Alluri Sitarama Raju Academy of Medical Sciences, Eluru, in the academic year 2024-2025. The Institutional Ethics Committee of ASRAM Medical College, Eluru (IEC No. 199/2025) approved the research ethically). Written informed consent was obtained from all participants before enrollment. A total of 100 participants were enrolled, including 50 sportspersons and 50 sedentary individuals. Equal numbers of male and female participants were included in both groups.

Eligibility Criteria

Inclusion Criteria

- Age between 18 and 21 years
- Female participants with an average height of approximately 150 cm and male participants with an average height of approximately 165 cm (to minimize the influence of body size on muscle thickness measurements)
- Sportspersons with a minimum of five years of structured training in football or basketball (activities which involve more running)
- Sedentary individuals with the history of performing less than 150 minutes of moderate physical activity per week and not participating in organized sports during the preceding five years.

Exclusion Criteria

- Previous history of lower-limb injury
- Inconsistent sports participation during the previous years
- Significant deviation from predetermined height criteria
- Current or previous use of corticosteroids

Data Collection and Ultrasonographic Assessment

Muscle thickness of the gastrocnemius and soleus and the length of the tendo calcaneus were measured using ultrasonography in the Department of Radiology, ASRAMS, Eluru. Participants were positioned prone with the ankle maintained at 90° to standardize measurements. Measurements were obtained using a 7–12 MHz linear-array transducer at the midpoint between the popliteal crease and starting point of Tendocalcaneus. All measurements were performed on the dominant limb by a single experienced radiologist.

Outcome Measures

- Gastrocnemius muscle thickness (cm)
- Soleus muscle thickness (cm)
- Proportional gastrocnemius thickness (gastrocnemius/soleus × 100)
- Tendo calcaneus length (cm)

Statistical Analysis

Data were entered into Microsoft Excel and analyzed using IBM SPSS Statistics version 22.0 (IBM Corp., Armonk, NY, USA). Continuous variables were expressed as mean ± standard deviation (SD). The normality of data distribution was assessed using the Shapiro–Wilk test. Since the data were normally distributed, comparisons between athletes and sedentary individuals were performed using the Independent Samples t-test. Comparisons were conducted separately for male and female participants. The proportional gastrocnemius thickness was calculated using the formula:

Gastrocnemius Proportion (%)=Gastrocnemius Thickness/ Soleus Thickness ×100

Effect size was estimated using Cohen's d to determine the magnitude of differences between groups. Results were presented with 95% confidence intervals (CI) wherever applicable. A p-value < 0.05 was considered statistically significant.

RESULTS

Table 1. Comparison of Gastrosoleus Morphology Between Female Athletes and Sedentary Individuals

Parameter	Athletes (n=25) Mean ± SD	Sedentary (n=25) Mean ± SD	t-value	p-value
Gastrocnemius thickness (cm)	1.32 ± 0.15	0.94 ± 0.12	4.12	0.001*
Soleus thickness (cm)	3.29 ± 0.21	3.29 ± 0.19	0.00	1.000
Gastrocnemius/Soleus ratio (%)	40.12 ± 4.6	28.57 ± 3.9	5.43	<0.001*
Tendocalcaneus length (cm)	12.0 ± 0.8	12.0 ± 0.7	0.00	1.000

Table 2. Comparison of Gastrosoleus Morphology Between Male Athletes and Sedentary Individuals

Parameter	Athletes (n=25) Mean ± SD	Sedentary (n=25) Mean ± SD	t-value	p-value
Gastrocnemius thickness (cm)	1.33 ± 0.14	0.94 ± 0.13	4.56	<0.001*
Soleus thickness (cm)	3.68 ± 0.25	3.75 ± 0.22	-0.72	0.481
Gastrocnemius/Soleus ratio (%)	36.14 ± 4.2	25.06 ± 3.6	5.02	<0.001*
Tendocalcaneus length (cm)	14.0 ± 0.9	14.0 ± 0.8	0.00	1.000

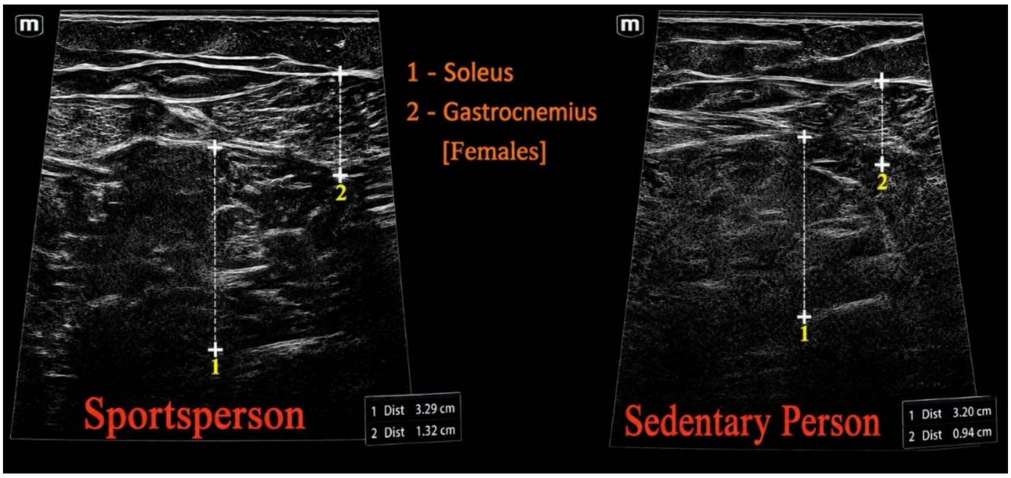

Figure 1. Ultrasound comparison of gastro-soleus muscle thickness in female subjects. The left panel shows a sportsperson, while the right panel shows a sedentary individual. Labels: 1 – Soleus, 2 – Gastrocnemius

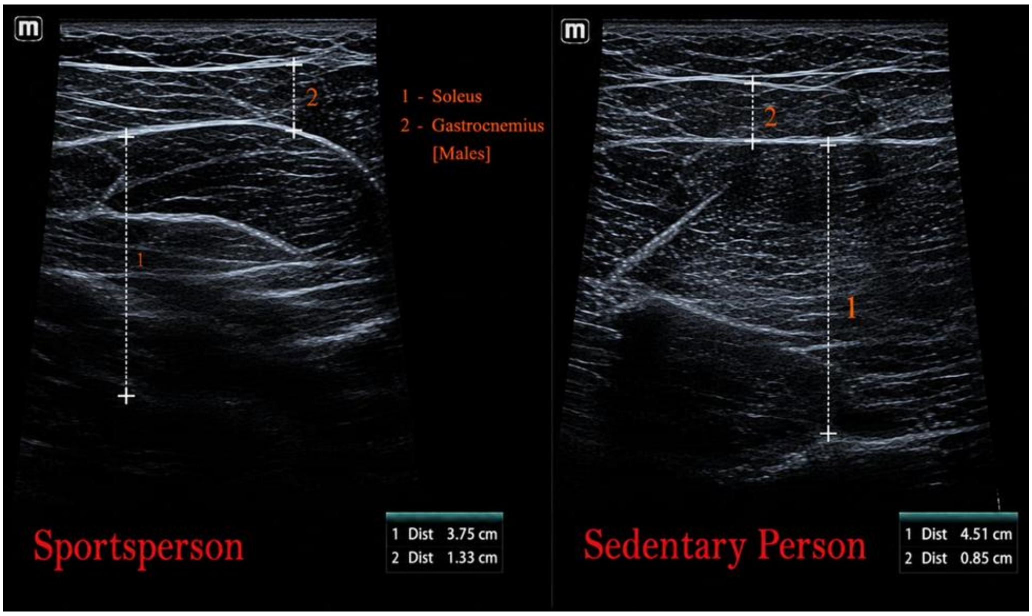

Figure 2. Ultrasound comparison of gastrosoleus muscle thickness in male subjects. The left panel shows a sportsperson; the right panel shows sedentary individual. Labels: 1 – Soleus, 2 – Gastrocnemius.

Figure 3.Normal positioning of the participants during ultrasonographic measurement procedure.

Interpretation:

The sample size of the study was 100 participants who comprised 50 sportspersons and 50 sedentary people, with a balanced gender representation.

In female participants, the gastrocnemius muscle thickness was higher in sportspersons (1.32 cm) than in sedentary people (0.94 cm). Conversely, the soleus thickness did not change significantly since the soleus was similar in both groups at 3.29 cm, and tendo calcaneus length did not change as well since it was 14 cm long. The proportional gastrocnemius-to-soleus thickness ratio was also greater among sportspersons (40.12%) compared with sedentary individuals (28.57%) (Table 1; Figure 1).

Among male participants, gastrocnemius thickness was similarly higher in sportspersons (1.33 cm) compared with sedentary individuals (0.94 cm). Soleus thickness demonstrated minimal variation between groups (3.68 cm -3.75 cm), and tendo calcaneus length without much difference ranging between 15.6 cm-16cm. The proportional gastrocnemius-to-soleus ratio was greater among sportspersons (36.14%) than sedentary individuals (25.06%) (Table 2; Figure 2).

Overall, ultrasonographic analysis demonstrated significantly increased gastrocnemius thickness and proportional gastrocnemius contribution among sportspersons in both sexes, indicating selective muscular adaptation associated with regular athletic training. No significant differences were observed in soleus thickness or tendocalcaneus length (Tables 1–2; Figures 1–2).

DISCUSSION

The present study demonstrated significantly greater gastrocnemius muscle thickness among sportspersons compared with sedentary individuals, whereas soleus thickness and tendo calcaneus length remained relatively unchanged (Tables 1–2; Figures 1–2). These findings support the concept of activity-specific adaptation within the triceps surae complex. The findings demonstrated greater gastrocnemius muscle thickness in athletes than in sedentary individuals, indicating the influence of regular physical training on muscle morphology.

These findings are consistent with previous reports demonstrating that chronic mechanical loading and athletic training stimulate skeletal muscle hypertrophy and architectural adaptations (4,5,11).

These findings are consistent with May et al., who reported greater gastrocnemius architectural characteristics among elite athletes due to chronic mechanical loading and sport-specific training adaptations(14). Similarly, Kanehisa et al. observed significant variations in gastrocnemius and soleus thickness according to sex and physical characteristics, supporting the role of habitual physical activity in influencing muscle morphology (13).In the current study, soleus muscle thickness was considerably greater than gastrocnemius thickness in both groups, with males exhibiting higher values than females. This finding is consistent with the anatomical functions of soleus being a strong postural muscle that has a bigger physiological cross-sectional area and is dominated by type I muscle fibres. The earlier ultrasound-based studies conducted by De-la-Cruz-Torres et al. also verified the usefulness of ultrasonography in assessing the soleus morphology in athletic groups(15,16). The augmentation of the triceps surae complex in athletes could be responsible as the strength of the plantarflexor, locomotor efficiency and better athletic performance.

Thickness of soleus muscle was significantly higher than the thickness of gastrocnemius muscle in the males and females respectively in the current study. This observation is anatomically and physiologically possible since the soleus is a large postural muscle that is mainly made of type I muscle fibers and is active when standing, walking, and locomoting. The increased thickness of the soleus muscle could be due to its ongoing functional requirements and increased physiological cross-sectional area. These results are consistent with the report of Kanehisa et al. (13), who found that there were significant differences in lower-limb muscle thickness according to sex and levels of physical activity.

The greater contribution of gastrocnemius thickness in athletes is in favor of the functional adjustment to more powerful output and explosive movement. Past electromyographic and biomechanical experiments have also indicated a higher recruitment of gastrocnemius during high-speed tasks and a higher recruitment of soleus during posture tasks [11].

Moreover, ultrasound imaging was an effective, reliable and non-invasive modality to assess muscle morphology in this study (Figure 3). Current systematic reviews uphold its usefulness in sport and musculoskeletal evaluation [6,7].

Differences were also noted with respect to gender with the males showing a more impressive soleus muscle thickness compared to females. The observation is in line with earlier literature that suggests that males typically have larger skeletal muscle mass and muscle cross-sectional area because of hormonal effects and body composition variations (13). The trend of increased soleus thickness compared to gastrocnemius thickness was however found in both sexes, which indicates the predominant structural role of the soleus in the triceps surae complex.

Table 3- comparison of present study with the similar studies

Author (Year)	**Study Population**	**Methodology**	**Major Findings**	**Comparison with Present Study**
Kanehisa et al.(2009) [13]	Healthy males and females	Ultrasonographic measurement of lower limb muscles	Muscle thickness varied according to sex and physical activity level; males demonstrated greater muscle thickness than females	Similar findings observed in the present study, where males showed greater soleus thickness than females and athletes demonstrated greater gastrocnemius thickness.
May et al. (2021) [14]	Elite basketball players and cyclists	Ultrasound assessment of gastrocnemius architecture	Athletes exhibited greater gastrocnemius muscle architecture adaptations due to chronic training	Consistent with the present study, which demonstrated significantly greater gastrocnemius thickness among sportspersons compared with sedentary individuals.
Vigotsky et al. (2021) [4]	Systematic review of resistance-trained individuals	Review of muscle architectural adaptations	Resistance training resulted in muscle hypertrophy and architectural remodeling	Supports the present findings of selective gastrocnemius hypertrophy associated with regular athletic activity.
Timmins et al. (2021) [5]	Athletes undergoing training	Ultrasound and architectural assessment	Training increased muscle thickness and altered muscle architecture	Similar to the present study, where athletes showed greater gastrocnemius thickness and

Author (Year)	Study Population	Methodology	Major Findings	Comparison with Present Study
	interventions			higher gastrocnemius-to-soleus ratios.
Magnusson & Kjaer (2003) [12]	Runners and non-runners	Achilles tendon morphological assessment	Reported regional differences in Achilles tendon morphology associated with training	Unlike their findings, the present study found no significant difference in tendo calcaneus length between athletes and sedentary individuals.
De-la-Cruz-Torres et al. (2021) [15]	Athletes with soleus pathology	Ultrasound evaluation of soleus morphology	Confirmed reliability of ultrasound in assessing soleus characteristics	Agrees with the present study regarding the usefulness of ultrasonography for evaluation of gastrosoleus morphology.
Hodson-Tole & Lai (2019) [17]	Healthy adults during walking and running	Dynamic ultrasound analysis	Demonstrated functional adaptations of plantar-flexor muscles during locomotion	Supports the concept that gastrocnemius and soleus muscles adapt according to functional demands, consistent with our observations.
Present Study (2025)	50 sportspersons and 50 sedentary individuals	Ultrasonographic assessment of gastrocnemius, soleus, and tendo calcaneus	Significant increase in gastrocnemius thickness and gastrocnemius-to-soleus ratio among athletes; no significant difference in soleus thickness or tendo calcaneus length	Demonstrates activity-specific hypertrophy of the gastrocnemius muscle associated with long-term sports participation.

The practical implications of the current research in the areas of sports medicine, physiotherapy, and sports performance measurement are evident. The increased muscularity in the sportspersons could lead to the development of a better plantar-flexor force, locomotor efficiency and a decrease in the incidence of injury. The knowledge of morphological changes that comes with athletic training can help clinicians and coaches to develop specific exercise and rehabilitation programs.
The study has certain limitations. The sample was relatively small and members of the various sporting disciplines were clustered together which could have drowned out sport-specific adaptations. Also, the cross-sectional design cannot draw a causal conclusion with regard to the relationship between training and muscle morphology. It is important to note that future longitudinal research with bigger cohorts and sport specific studies should be carried out to explore further the adaptations of the gastrocnemius- soleus-tendocalcaneus complex.

CONCLUSION

The current paper has shown that selective hypertrophy of gastrocnemius muscle is related to the regular sports activity, whereas the thickness of the soleus muscle and the length of the tendo calcaneus do not change significantly. The higher proportion of contribution of gastrocnemius seen among sportspersons indicates the functional adjustment to the power production and performance of explosive movements. The results support the idea that skeletal muscle adaptation is particular to training demands and muscle activity. Moreover, ultrasonography was a convenient, dependable and non-invasive way of assessing the morphology of lower-limb muscles. It is suggested that more research in future, using bigger samples and incorporating various sporting activities in sprinters, will be suitable to comprehend sport-specific variations in the gastrosoleus complex

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