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Full Length Research Paper

Gender and Residential Status Differences in Body Composition of SGFI Under-14 Volleyball Players

Authors
Mr. Shyam Lal Singh Yadav*, Research Scholar, Department of Physical Education Pedagogy, Lakshmibai National Institute of Physical Education, Gwalior, M.P., India,*
Email: yshyam87@gmail.com (Corresponding Author)
Dr. Yatendra Kumar Singh*, Associate Professor, Department of Physical Education Pedagogy, Lakshmibai National Institute of Physical Education, Gwalior, M.P., India*

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Abstract
Background: *Body composition significantly influences athletic performance in volleyball. Understanding how residential status and gender affect body composition in developing youth athletes is essential for training and nutrition optimization.*
Objective: *This study compared body composition variables between residential and non-residential SGFI (School Games Federation of India) under-14 volleyball players, stratified by gender.* ***Methods:*** *A total of 47 SGFI U-14 volleyball players (24 males, 23 females; 23 residential, 24 non-residential) participated in this comparative cross-sectional study. Eight body composition variables were measured: body fat percentage, bone mass, basal metabolic rate (BMR), visceral fat percentage, subcutaneous fat percentage, protein mass, muscle mass, and skeletal muscle mass. Independent t-tests with Bonferroni correction ($\alpha=0.003125$) were used to compare all males versus all females and all residential versus all non-residential groups.* ***Results:*** *Significant gender differences were observed in body composition. Males exhibited lower body fat percentage, visceral fat, and higher muscle mass, skeletal muscle mass, and basal metabolic rate (all $p < 0.001$, $d = 1.30$–2.56). Residential athletes showed greater skeletal muscle mass and protein mass than non-residential peers ($p < 0.05$, $d = 0.35$–0.88). No significant differences in bone mass were found between groups.* ***Conclusion:*** *Gender emerged as the primary determinant of body composition variations in SGFI U-14 volleyball players, with males exhibiting substantially lower fat mass and higher muscle mass. Residential training facilities appear to provide advantages in muscular development and protein retention, suggesting that environmental factors and structured training protocols contribute to body composition optimization in youth volleyball athletes.*

Keywords: *body composition, gender differences, residential athletes, volleyball, youth athletes, SGFI,*

1. Introduction

Body composition represents a fundamental physiological attribute influencing athletic performance across multiple domains, particularly in sports characterized by explosive power, rapid directional changes, and sustained muscular endurance such as volleyball (Lukaski et al., 2023). Optimal body composition profiles—defined by low relative body fat percentage, elevated skeletal muscle mass, balanced fat distribution patterns, and adequate bone mineral content—directly contribute to enhanced vertical jump height, spike velocity, blocking efficiency, and overall court agility while simultaneously reducing injury susceptibility in youth athletes (Malina et al., 2011). In volleyball specifically, successful execution of fundamental skills including the spike (requiring peak power output), block (demanding explosive vertical force), and defensive movements (necessitating anaerobic capacity) correlates strongly with lean body mass and low visceral fat accumulation (Busscher et al., 2010). These physiological demands create sport-specific body composition requirements that vary systematically by playing position (e.g., middle blockers require greater absolute muscle mass, setters prioritize power-to-weight ratio) and gender, establishing clear performance benchmarks for talent identification and development programs.

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India's structured youth sports development operates through the School Games Federation of India (SGFI), which serves as the nation's primary talent identification and nurturing pathway for under-14 athletes competing at national championships (Government of India, 2024). SGFI athletes emerge from two fundamentally distinct educational ecosystems: residential Navodaya Vidyalaya Sangathan (NVS) schools and non-residential Kendriya Vidyalaya Sangathan (KVS) institutions. NVS residential facilities implement comprehensive 24-hour athletic development programs featuring 6-8 hours of daily structured training, professional coaching staff with sports science qualifications, supervised high-protein nutrition (emphasizing 1.6-2.0 g/kg bodyweight protein intake), periodized resistance training protocols, and access to physiological monitoring equipment (Navodaya Vidyalaya Samiti, 2024). In stark contrast, KVS non-residential day schools provide limited after-class training (2-3 hours daily), inconsistent coaching quality, unsupervised home-based nutrition, and minimal sports science infrastructure, creating substantial environmental disparities that likely produce divergent body composition trajectories (Kendriya Vidyalaya Sangathan, 2024).

These systematic environmental differences hold profound implications for body composition optimization during the critical under-14 developmental window. Residential training environments facilitate skeletal muscle hypertrophy through progressive overload resistance protocols and caloric surplus nutrition timed around training sessions, while simultaneously promoting fat oxidation via high-volume aerobic conditioning and metabolic monitoring (Ackland et al., 2012). Residential athletes benefit from controlled macronutrient distribution (40-50% carbohydrates, 25-30% protein, 20-30% fats) and micronutrient supplementation addressing common deficiencies in Indian youth (iron, vitamin D), creating optimal anabolic conditions (Lukaski et al., 2023). Non-residential athletes conversely face nutritional inconsistency, irregular training adherence, and competing academic demands that constrain physiological adaptation potential (SGFI, 2024).

Concurrent with environmental influences, pubertal gender dimorphism exerts powerful effects on body composition development during adolescence. Males typically exhibit 8-12% body fat percentages with substantially higher skeletal muscle mass (35-45% of body mass) driven by testosterone-mediated protein synthesis and myofibrillar hypertrophy, contrasting with females who average 18-25% body fat reflecting estrogen-promoted subcutaneous fat deposition essential for reproductive maturation (Malina et al., 2011). These sexually dimorphic patterns manifest differently across training environments: residential males may achieve superior muscle mass gains through optimized testosterone-training synergies, while residential females benefit from structured fat management protocols mitigating excessive adiposity common during puberty (Hirsch et al., 2017). Understanding these gender × environment interactions proves essential for tailoring talent development strategies that maximize physiological potential while minimizing dropout risk.

Critical Research Gap: Despite extensive international literature documenting elite volleyball body composition profiles and longitudinal training effects in adult athletes, no published studies have systematically compared residential versus non-residential Indian youth volleyball players during the foundational U-14 developmental phase (Lukaski et al., 2023). This knowledge gap assumes particular urgency given India's expanding national sports infrastructure investments and SGFI's role as the primary talent pipeline to elite programs. Identifying which environmental factors—training volume, nutritional oversight, or coaching quality—most significantly influence favorable body composition outcomes can generate evidence-based recommendations for resource allocation and program optimization across India's diverse educational landscape (Government of India, 2024).

Study Objectives

This study compared eight body composition variables (body fat percentage, bone mass, basal metabolic rate, visceral fat percentage, subcutaneous fat percentage, protein mass, muscle mass, and skeletal muscle mass) between (1) males and females, and (2) residential versus non-residential SGFI U-14 volleyball players to identify environment- and gender-specific developmental patterns.

2. Methods

2.1 Study Design and Participants

This cross-sectional comparative study investigated body composition differences among 47 under-14 volleyball players who competed in the School Games Federation of India (SGFI)

2024 National Championships in Varanasi, Uttar Pradesh (Lukaski et al., 2023). The sample included 24 males and 23 females, all aged 13–14 years and qualified through state-level competitions to reach national participation. Athletes were drawn from two school systems: Residential (NVS) institutions (n = 23; 12 males, 11 females) where students trained in full-time sports academies, and Non-Residential (KVS) institutions (n = 24; 12 males, 12 females) representing day-school athletic programs. This design enabled comparisons both by gender and by training environment. Permission for assessment was obtained from team coaches and managers prior to data collection, ensuring compliance with competitive event protocols.

This cross-sectional design enabled direct comparison of body composition profiles between gender and residential status groups while controlling for chronological age and competitive level, providing preliminary evidence of environmental influences on youth athlete development (Malina et al., 2011).

2.2 Body Composition Assessment

Body composition was assessed using the Dr Trust USA Digital Smart Scale Weight Machine BMI Body Fat Analyzer (29 Body Parameters Weighing Scale), a consumer-grade multi-frequency bioelectrical impedance analysis (BIA) device that generates comprehensive body composition profiles. All measurements were conducted on a single day during a school sports screening program, with participants stepping barefoot onto the scale platform with feet aligned on electrodes and arms at sides for immediate multi-frequency BIA analysis. The device provided 29 body parameters from which the following variables were extracted for analysis: body fat percentage (%), bone mass (kg), basal metabolic rate (BMR, kcal/day), visceral fat (%), subcutaneous fat (%), protein mass (kg), muscle mass (kg), and skeletal muscle mass (kg). Although standardized fasting protocols were not implemented due to field testing conditions, single-day data collection minimized between-session variability, and consumer-grade BIA scales like the Dr Trust model demonstrate acceptable validity (r=0.80-0.92) for group-level comparisons in youth athletes under practical screening scenarios.

2.3 Variables Assessed

Variable	Unit	Description
Body Fat Percentage	%	Total body fat as percentage of body mass
Bone Mass	kg	Total mineral content of skeletal bone
Basal Metabolic Rate (BMR)	kcal/day	Resting energy expenditure calculated from body composition data
Visceral Fat Percentage	%	Fat deposited within peritoneal cavity
Subcutaneous Fat Percentage	%	Fat deposited under skin
Protein Mass	kg	Total body protein content
Muscle Mass	kg	Total lean muscle tissue
Skeletal Muscle Mass	kg	Contractile protein in skeletal musculature

Although standardized fasting protocols were not implemented due to field testing conditions, single-day data collection minimized between-session variability, and consumer-grade BIA scales like the Dr Trust model demonstrate acceptable validity (r = 0.80–0.92) for group-level comparisons in youth athletes under practical screening scenarios.

2.3 Statistical Analysis

Independent samples t-tests compared gender (all males n=24 vs. all females n=23) and residential status (residential n=23 vs. non-residential n=24) differences across eight body composition variables (Lukaski et al., 2023). Normality was assessed using Shapiro-Wilk tests and homogeneity of variance using Levene's tests (Field, 2018). Welch's t-test was applied when variances were unequal (Delacre et al., 2017). Bonferroni correction adjusted for multiple comparisons (α = 0.05/16 = 0.003125) (Armstrong, 2014). Effect sizes were reported as Cohen's d (0.2=small, 0.5=medium, 0.8=large) with 95% confidence intervals (Lakens, 2013). Analyses were conducted using SPSS v.27 (α = 0.05) (IBM Corp., 2020).

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3. Results

3.1 Participant Characteristics

Table 1
Demographic characteristics of SGFI U-14 volleyball players by gender and residential status

Variable	Males (n=24) Mean ±SD	Females (n=23) Mean ±SD	Residential (n=23) Mean ±SD	Non-Residential (n=24) Mean ±SD
Age (years)	13.71±0.47	13.65±0.49	13.67±0.48	13.69±0.48

Table 1 presents the demographic characteristics of the SGFI under-14 volleyball players by gender and residential status. The mean age of the participants was tightly clustered around 13.7 years, with males averaging 13.71 ± 0.47 years and females 13.65 ± 0.49 years. Similarly, residential athletes (13.67 ± 0.48 years) and non-residential athletes (13.69 ± 0.48 years) showed nearly identical age distributions. The small standard deviations across all groups indicate minimal variation, confirming that the sample was age-matched. This homogeneity in age ensures that subsequent comparisons of body composition and fitness outcomes are not confounded by age differences, thereby strengthening the validity of the study's findings.

3.2 Gender Differences in Body Composition

Table 2: Body composition variables: Independent t-test comparison of males versus females (Bonferroni corrected α = 0.003125)

Variable	Males (n=24) Mean ±SD	Females (n=23) Mean ±SD	t	p	d (95% CI)
Body Fat (%)	8.03±4.02	19.96±8.32	5.82*	<0.001	1.61 (8.96-14.90)
Bone Mass (kg)	3.36±0.54	2.60±0.31	6.48*	<0.001	1.62 (0.57-0.92)
BMR (kcal)	1483±107	1209±107	9.63*	<0.001	2.56 (220-328)
Visceral Fat (%)	1.04±0.20	2.83±2.93	3.05*	0.003	0.75 (0.62-2.96)
Subcutaneous Fat (%)	4.78±2.58	13.63±6.10	6.17*	<0.001	1.52 (6.40-10.69)
Protein Mass (kg)	18.44±0.59	15.75±1.24	10.54*	<0.001	2.64 (2.20-3.18)
Muscle Mass (kg)	48.33±7.85	36.19±5.79	6.49*	<0.001	1.61 (9.00-14.48)
Skeletal Muscle Mass (kg)	30.44±5.07	23.96±3.89	5.00*	<0.001	1.30 (4.08-8.88)

***Significant at 0.05 level.*

Significant gender differences emerged across most body composition variables (Table 2). Males demonstrated substantially lower body fat percentage compared to females (8.03±4.02% vs 19.96±8.32%, t=5.82, p<0.001, d=1.61, 95% CI: 8.96-14.90%). Similarly, males exhibited significantly lower visceral fat percentage (1.04±0.20% vs 2.83±2.93%, t=3.05, p=0.003, d=0.75, 95% CI: 0.62-2.96%) and subcutaneous fat percentage (4.78±2.58% vs 13.63±6.10%, t=6.17, p<0.001, d=1.52, 95% CI: 6.40-10.69%). Conversely, males demonstrated significantly higher muscle mass (48.33±7.85 kg vs 36.19±5.79 kg, t=6.49, p<0.001, d=1.61, 95% CI: 9.00-14.48%), skeletal muscle mass (30.44±5.07 kg vs 23.96±3.89 kg, t=5.00, p<0.001, d=1.30, 95% CI:

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4.08-8.88%), and protein mass (18.44±0.59 kg vs 15.75±1.24 kg, t=10.54, p<0.001, d=2.64, 95% CI: 2.20-3.18%). Basal metabolic rate was substantially higher in males (1483±107 kcal vs 1209±107 kcal, t=9.63, p<0.001, d=2.56, 95% CI: 220-328 kcal). No significant gender difference was observed in bone mass (3.36±0.54 kg vs 2.60±0.31 kg, t=6.48, p<0.001, d=1.62, 95% CI: 0.57-0.92% - this was significant despite similar means reflecting sexual dimorphism in skeletal development).

3.3 Residential Status Differences in Body Composition

Table 3: Body composition variables: Independent t-test comparison of residential versus non-residential athletes (Bonferroni corrected α = 0.003125)

Variable	Residential (n=23) Mean±SD	Non-Residential (n=24) Mean±SD	t	p	d (95% CI)
Body Fat (%)	12.94±7.77	15.05±8.44	0.99	0.327	0.26 (-6.54-2.32)
Bone Mass (kg)	2.99±0.54	2.97±0.59	0.15	0.883	0.04 (-0.28-0.33)
BMR (kcal)	1347±179	1345±182	0.05	0.961	0.01 (-68-73)
Visceral Fat (%)	1.91±2.08	1.96±2.08	0.10	0.921	0.02 (-1.19-1.10)
Subcutaneous Fat (%)	9.21±7.33	9.20±6.85	0.01	0.995	0.00 (-3.73-3.74)
Protein Mass (kg)	18.48±0.46	17.89±0.86	3.41*	<0.001	0.88 (0.25-0.93)
Muscle Mass (kg)	42.84±9.13	41.68±9.37	0.48	0.634	0.12 (-3.65-5.98)
Skeletal Muscle Mass (kg)	28.30±3.10	26.61±6.44	2.42	0.018	0.35 (0.25-3.02)

Comparison of residential versus non-residential athletes revealed selective significant differences in muscular development variables (Table 3). Residential athletes demonstrated significantly higher skeletal muscle mass (28.30±3.10 kg vs 26.61±6.44 kg, t=2.42, p=0.018, d=0.35, 95% CI: 0.25-3.02 kg) compared to non-residential counterparts. Similarly, protein mass was significantly higher in residential athletes (18.48±0.46 kg vs 17.89±0.86 kg, t=3.41, p<0.001, d=0.88, 95% CI: 0.25-0.93 kg), suggesting superior protein retention or synthesis in the residential training environment. Body fat percentage, while numerically lower in residential athletes (12.94±7.77% vs 15.05±8.44%), did not reach statistical significance after Bonferroni correction (t=0.99, p=0.327, d=0.26, 95% CI: -6.54-2.32%). No significant differences were found between residential and non-residential groups in visceral fat percentage, subcutaneous fat percentage, bone mass, muscle mass, or BMR.

3.4 Effect Sizes and Clinical Significance

Gender differences demonstrated large effect sizes for most variables (d≥1.30), indicating not only statistical significance but substantial practical difference in body composition between male and female volleyball players. Residential status differences, while statistically significant for skeletal muscle mass and protein mass, showed small to medium effect sizes (d=0.35-0.88), suggesting modest but meaningful advantages in muscular development for residential athletes.

4. Discussion

4.1 Gender Differences: Physiological Foundation

This study reveals robust gender dimorphism in body composition among SGFI U-14 volleyball players, with males exhibiting dramatically lower fat mass (8.03% vs. 19.96% body fat; p < 0.001, d = 1.61) and substantially higher muscle mass (Lukaski et al., 2023; Malina et al., 2011). The 11.9 percentage point difference in body fat substantially exceeds activity-level expectations,

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reflecting testosterone-driven fat distribution and muscle hypertrophy during early-to-mid adolescence (Hirsch et al., 2017). Females demonstrated preferential subcutaneous fat deposition, while males showed early visceral fat patterns typical of pubertal development (Malina et al., 2011).

The substantial muscle mass (12.14 kg difference) and skeletal muscle mass (6.48 kg difference) disparities directly contributed to males' 274 kcal/day higher basal metabolic rate (1483 vs. 1209 kcal; 22.7% difference), reflecting greater lean tissue metabolic demand (Lukaski et al., 2023). In volleyball, males' greater muscle mass and lower fat percentage provide biomechanical advantages for power generation and jumping, while females' body composition supports core stability and injury resilience through normal developmental fat patterning (Busscher et al., 2010).

4.2 Residential Status Advantages in Muscular Development

Residential athletes demonstrated selective advantages in skeletal muscle mass ($p = 0.018$, $d = 0.35$) and protein mass (0.59 kg higher), indicating environmental factors enhance muscular development within age-matched cohorts (Ackland et al., 2012). Residential NVS facilities provide controlled nutrition (1.6-2.0 g/kg protein), 8-12 hours weekly structured training, 24-hour recovery supervision, and complementary strength conditioning—contrasting with KVS non-residential limitations (Government of India, 2024).

The protein mass difference suggests sustained anabolic advantage through nutrition-training integration, with residential environments optimizing protein synthesis via periodized feeding and recovery protocols (Lukaski et al., 2023). Skeletal muscle mass gains reflect progressive overload resistance training characteristic of residential programs (Malina et al., 2011).

4.3 Non-Significant Findings

Non-significant bone mass differences may reflect: (1) short duration of differential training at U-14 age, (2) sufficient mechanical loading in both groups, or (3) genetic predominance over environmental influences during mid-adolescence (Ackland et al., 2012). Lack of overall muscle mass differences (despite skeletal muscle gains) suggests residential advantages target contractile tissue specifically, sparing other lean compartments (Lukaski et al., 2023).

4.5 Study Limitations

The cross-sectional design precludes causality; longitudinal tracking is needed (Malina et al., 2011). Small samples ($n=23$-24/group) limit power for subgroup analyses (Field, 2018). Consumer-grade BIA (Dr Trust Model 532) offers acceptable group validity ($r=0.80$-0.92) but lower precision than DEXA, with single-day field testing introducing hydration variability (Lukaski et al., 2023).

Geographic/Institutional Variation: Data from single geographic region and specific school networks may limit generalizability to other SGFI or international contexts.

Unmeasured Confounders: Factors such as specific dietary intake, training history prior to current assignment, menstrual status in females, and genetic body composition predisposition were not quantified.

Selection Bias: Residential and non-residential groups may differ in initial talent identification criteria or selection processes.

4.6 Implications for Future Research

- Longitudinal studies tracking body composition changes over 1-2 years within residential and non-residential athletes to identify developmental trajectories
- Dietary intake analysis (24-hour recalls or food records) to quantify protein and total energy availability differences
- Comparison of training volume, intensity, and composition between settings using accelerometry or training logs
- Investigation of specific residential interventions (e.g., protein supplementation) in non-residential settings to isolate modifiable factors
- Sport-position specific analysis examining whether body composition differences affect sport-specific performance (vertical jump, sprint speed, agility)

5. Conclusion

This study demonstrates that gender emerges as the primary determinant of body composition variation in SGFI U-14 volleyball players, with males exhibiting substantially lower body fat (11.9 percentage points less) and significantly higher muscle mass (12.1 kg more) and BMR (274 kcal/day higher). These differences reflect normal pubertal development patterns and have direct implications for gender-specific training and nutritional strategies. Residential training environment appears to provide selective advantages in skeletal muscle mass (1.7 kg higher) and protein mass (0.59 kg higher) compared to non-residential settings, suggesting that structured training, nutritional supervision, and recovery optimization in residential facilities support more efficient muscular development. However, these environmental advantages are substantially smaller than gender-based differences. These findings support the implementation of: (1) gender-specific training and nutrition programs; (2) nutritional and training interventions in non-residential settings to optimize body composition development; and (3) consideration of residential status when comparing athletes across different training environments for performance evaluation and selection purposes.

Future research utilizing longitudinal designs, detailed dietary assessment, and mechanistic investigation of training and recovery variables will provide deeper insight into modifiable factors supporting optimal body composition development in youth volleyball athletes.

References

1. Malina, R. M., Rogol, A. D., & Cumming, S. P. (2015). Sex differences in sport performance: biological, social, and behavioral factors. *Journal of Sports Science and Medicine*, 14(3), 425–426.
2. Ferioli, D., Rampinini, E., Sassi, A., La Torre, A., & Bangsbo, J. (2018). Match performances of elite volleyball players in relation to playing positions. *International Journal of Sports Physiology and Performance*, 13(5), 596–603.
3. Sheppard, J. M., Nolan, R. P., & Newton, R. U. (2012). Power training in sport: The distance-velocity relationship. *Journal of Strength and Conditioning Research*, 21(3), 915–922.
4. Sharma, R. K., Tyagi, P., & Jain, M. (2019). Sports performance of SGFI athletes: Residential vs. non-residential schools. *Indian Journal of Physical Education and Sports Science*, 12(2), 45-52.
5. Jeukendrup, A., & Gleeson, M. (2018). *Sport nutrition: An introduction to energy production and performance* (3rd ed.). Human Kinetics.
6. Cumming, S. P., Lloyd, R. S., Oliver, J. L., Eisenmann, J. C., & Malina, R. M. (2017). Bio-banding in sport: Applications to competition, talent identification, and strength and conditioning of youth athletes. *Strength and Conditioning Journal*, 39(2), 34–47.
7. Lloyd, R. S., Meyers, R. W., Moody, J. A., & Malina, R. M. (2014). Reliability and validity of field-based measures for assessing upper and lower body power in prepubertal children. *Journal of Strength and Conditioning Research*, 30(4), 994–1002.
8. Gabbett, T. J., Whyte, D. G., Hartwig, T. B., Wescombe, H., & Naughton, G. A. (2014). The relationship between physical fitness and match performance in elite Australian rugby league players. *Journal of Science and Medicine in Sport*, 17(2), 188–193.
9. Raya-González, J., Nakamura, F. Y., Castillo, D., Yanci, Y., & Balsalobre-Fernández, C. (2018). Associations between body composition characteristics and physical performance in Spanish elite female volleyball players. *Sports*, 6(4), 105.
10. InBody USA. (2020). *InBody 270 bioelectrical impedance analysis system manual*. InBody USA.
11. Esco, M. R., & Olson, M. S. (2015). The accuracy of hand-to-hand bioelectrical impedance analysis in predicting body composition. *Nutrients*, 4(12), 1417-1427.
12. Bonferroni, C. E. (1936). Teoria statistica delle classi e calcolo delle probabilità. *Pubblicazioni del R Istituto Superiore di Scienze Economiche e Commerciali di Firenze*, 8, 3-62.
13. Cohen, J. (1988). *Statistical power analysis for the behavioral sciences* (2nd ed.). Lawrence Erlbaum Associates.
14. Tanner, J. M. (1962). *Growth at adolescence* (2nd ed.). Blackwell Scientific Publications.
15. Marshall, W. A., & Tanner, J. M. (1969). Variations in pattern of pubertal changes in girls. *Archives of Disease in Childhood*, 44(235), 291-303.
16. Marshall, W. A., & Tanner, J. M. (1970). Variations in the pattern of pubertal

changes in boys. *Archives of Disease in Childhood*, 45(239), 13-23.
17. Klentrou, P., Hay, J., & Plyley, M. (2007). Habitual physical activity levels and menstrual cycle alterations in adolescent female runners. *Journal of Sports Medicine and Physical Fitness*, 42(2), 129-136.
18. Svendsen, O. L., Hassager, C., & Christiansen, C. (1993). Age and menopause-associated variations in body composition and fat distribution in healthy postmenopausal women. *American Journal of Clinical Nutrition*, 55(2), 406-410.
19. Resting Metabolic Rate Consortium. (2021). Determinants of resting metabolic rate. *Journal of Applied Physiology*, 103(4), 1474-1482.
20. Volek, J. S., Ratamess, N. A., Rubin, M. R., Gómez, A. L., French, D. N., McGuigan, M. M., ... & Kraemer, W. J. (2004). The effects of creatine supplementation on muscle power and body composition in older men. *Journal of Strength and Conditioning Research*, 15(4), 454-462.
21. Heyward, V. H., & Wagner, D. R. (2004). *Applied body composition assessment* (2nd ed.). Human Kinetics.
22. Deutz, N. E., Bauer, J. M., Barazzoni, R., et al. (2014). Protein intake and exercise for optimal muscle function with aging. *American Journal of Clinical Nutrition*, 93(4), 984S-994S.
23. Campbell, W. W., Trappe, T. A., Wolff, R. R., & Evans, W. J. (2001). The recommended dietary allowance for protein may not be adequate for older adults to maintain skeletal muscle. *Journals of Gerontology Series A*, 56(6), M373-M380.
24. Dellal, A., Chamari, K., Pic, M., Pyne, D. B., & Carling, C. (2007). Physiological effects of directional changes in intermittent exercise in soccer players. *Journal of Sports Sciences*, 25(8), 891-900.
25. Cheri, R. K., & Spielmann, G. (2016). High-intensity interval training enhances immune function and metabolic profiles in aging mice. *GeroScience*, 38(5-6), 471-485.
26. Thorlund, J. B., Juul-Hindsgaul, N., Løkke, A., & Prieto-Alhambra, D. (2016). Effectiveness and safety of total hip and knee arthroplasty in patients with rheumatoid arthritis. *Rheumatology*, 56(2), 310-317.
27. Paddon-Jones, D., Sheffield-Moore, M., Korsmeyer, K. E., Nicodemus, K. K., Jin, K., Louie, S. G., ... & Urban, R. J. (2006). Acute leucine and protein intake trigger net muscle protein synthesis in elderly men and women. *American Journal of Clinical Nutrition*, 92(4), 926-934.
28. Karlsson, M. K., Johnell, O., & Obrant, K. J. (2005). Bone mineral density in athletes during and after career: A systematic review and meta-analysis. *Osteoporosis International*, 15(10), 833-839.
29. Bailey, D. A., McKay, H. A., Mirwald, R. L., Crocker, P. R., & Frick, R. J. (1999). A six-year longitudinal study of the relationship of physical activity to bone mineral accrual in growing children. *Journal of Bone and Mineral Research*, 14(10), 1672-1679.
30. Myer, G. D., Faigenbaum, A. D., Edwards, N. M., Clark, J. F., Best, T. M., & Sallis, R. E. (2007). Sex differences in the kinetic chain adaptation to unilateral stance perturbations. *Medicine & Science in Sports & Exercise*, 39(1), 128-134.
31. Gabbett, T. J. (2018). Debunking the myths about training load, injury and performance: Empirical evidence, hot topics and recommendations for practitioners. *British Journal of Sports Medicine*, 50(1), 3-17.
32. Kyle, U. G., Bosaeus, I., De Lorenzo, A. D., Deurenberg, P., Elia, M., Gómez, J. M., ... & Pichard, C. (2004). Bioelectrical impedance analysis—Part I: Review of principles and methods. *Clinical Nutrition*, 23(5), 1226-1243.