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A Two-Year Longitudinal Observation of Somatotype Changes among Youth Judo Practitioners

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Abstract

This prime purpose of the study was to examine longitudinal changes in anthropometric characteristics among youth judo athletes during a controlled and systematic training period. Ninety-three male judo athletes (baseline mean age 12.0±0.32 years; 14.0±0.32 years at final follow-up) were assessed every six months over two years. Anthropometric measurements followed International Society for the Advancement of Kinanthropometry (ISAK) standards. Fat-free mass (FFM) and somatotype components (endomorphy, mesomorphy, ectomorphy) were calculated using the Heath-Carter method. Linear mixed-effects models showed significant Phase effects for mid-calf skinfold ($p<0.001$), arm girth ($p=0.003$), calf girth ($p=0.012$), biepicondylar humerus breadth ($p=0.035$), biepicondylar femur breadth ($p<0.001$) and FFM ($p<0.001$). Estimated marginal means showed progressive increases in girths, skeletal breadths and FFM across Phases (FFM: 38.05 to 49.96 kg; arm girth: 23.9 to 28.9 cm; femur breadth: 6.68 to 7.76 cm), while biceps, triceps, subscapular and supra-spinale skinfolds remained unchanged (all $p>0.05$). Over 24 months, youth judo athletes demonstrated increased lean mass and structural growth with stable subcutaneous fat, indicating healthy maturation for young judo athletes in Northeast India.

Keywords: *kinanthopometry, combat sports, athlete development, linear mixed-effect model, youth sports*

Introduction

Recent studies on young judo athletes have further shown that anthropometric and developmental characteristics are closely related to physical performance, training experience and age-related progression in the sport (Detanico et al., 2020a; Fukuda et al., 2018; Torres-Luque et al., 2015). Judo athletes typically exhibit dominant mesomorphic somatotypes, reflecting the importance of muscle mass in meeting the sport's physical demands (Giudicelli et al., 2020a). Importantly, these mesomorphic attributes are significantly higher in judo players than in sedentary males (Busko et al., 2017; Katralli & Goudar, 2012). With greater mesomorphic attributes, judo players possess greater upper-body strength and explosiveness developed through their specific training programmes (Casals et al., 2016). At the same time, biological maturation also has an impact on the body types of youth judo players. Previous work has suggested that combining systematic training according to biological maturation can improve overall strength, agility and aerobic power in young judokas (Giudicelli et al., 2021; Kons et al., 2018).

Existing literature also provided some evidence which were relating somatotype in judo to the sport's competition structure (De Moraes Ferrari et al., 2015a; Kelley et al., 2015). As weight categories are predetermined for each bout in judo competitions, it can be expected that similar variability in body types exists among competitors in different weight classes and may therefore affect performance. The study by Roklicer et al. (2020) found differences in somatotype profiles among male and female judokas based on the competitor's weight class, with lightweight competitors being most likely to exhibit an ectomorphic-mesomorphic profile, while competitors in middle and heavyweight classes were most likely to exhibit an endomorphic-mesomorphic profile. These results supported the view that there was no ideal physique for competing in judo. Rather, body type must be viewed in conjunction with the constraints of the competitor's weight class and the specific demands of performance and training experience (Casals et al., 2016; Drapsin et al., 2020a; Hamzaoui et al., 2022). Therefore, adding anthropometry to understand the somatic traits of the judokas, could provide a clearer understanding of the sports' somatic traits.

Although significant advances have been made in this area of study, it remains underdeveloped in one important respect. Most studies investigating somatotype in judo have used a cross-sectional approach. Cross-sectional studies are beneficial because they allow researchers to identify typical somatotype profiles associated with competitive levels, compare athletes from different populations and investigate relationships between body type and performance indicators. However, they represent only one specific point in time. Therefore, such studies can describe the anthropometric and somatotype characteristics of athletes at a particular point in time without providing insight into how these profiles develop through long-term systematic training. The limitations associated with relying exclusively on cross-sectional studies in judo are important. This is because developmental evidence indicates that the anthropometric characteristics of young judokas may change over time in response to growth, regular training, and sport-specific adaptation (Detanico et al., 2020a; Fukuda et al., 2018; Phukon et al., 2023; Prieske et al., 2020a). This gap becomes even more pronounced when the focus shifts to youth judo practitioners in grassroots environments. While most young athletes participate in structured and regular practice throughout their years of development, there are very limited data on their body type over an extended period of time. Thus, while coaches and researchers may know the typical body type usually associated with judo athletes, there is limited research available on how and whether young athletes develop toward those profiles under actual training conditions. The implications of this limitation are significant. Without longitudinal data, it is difficult to determine whether changes in an athlete's body type are temporary, inconsistent, or part of a longer-term developmental pathway. Additionally, without longitudinal data, the usefulness of anthropometric assessments by coaches and researchers is limited when developing training programmes, tracking athlete progress and supporting the identification and development of talented athletes.

To address the aforementioned research gap, this study was conducted. The present study aimed to examine somatotype changes among youth judo practitioners over a two-year period of systematic training. This longitudinal study used repeated anthropometric measurements to assess changes in somatic characteristics during training in youth judo practitioners under supervised and controlled conditions. Present study expected that fat-free mass and mesomorphy would increase over time, reflecting the combined influence of growth and judo-specific training.

Material and methods

Participants

Ninety-three (N=93) tribal male youth judo athletes from Tripura State, India (mean age 12.0±0.32 years at baseline) were purposively selected. All participants represented Tripura in state and national competitions. Written consent was obtained from respective authorities, coaches and participants (verbal from minors). All data collection procedures followed the Declaration of Helsinki, with approval from University's Research Ethical and Advisory Committee (File No. F/TU/COE/10/PHE/25/24).

Study design

This longitudinal study was structured into five distinct phases to observe changes over time in response to judo training. At Phase 0, all the participants had completed a 6-month generalized conditioning period, but had not yet begin formal judo-specific training. This Phase 0, provided baseline data. Subsequent Phases were scheduled at six-month intervals after the initiation of structured judo training. Specifically:

Phase 0: Initial Observation

Phase 1: Data were collected after 6 months of judo training.

Phase 2: Data were collected after 12 months of training.

Phase 3: Data were collected after 18 months of training.

Phase 4: Final data collection occurred after 24 months of continuous judo training.

All the anthropometric measurements were collected according to the procedures given by ISAK (The International Society for Advancement of Kinanthopometry) and somatotypes were calculated using Heath & Carter method. In the following Table 1, tools and equipment used for anthropometric measurements is being mentioned.

Table 1. Anthropometric measurement sites, equipment, and units

Sites for the measurements	Equipments used	Units of measure
Standing stature	Stadiometer (Seca 213)	Centimetre (cm)
Body mass	Weighing machine (BeatXP Digital weighing machine)	Kilogram (kg)
Four skinfolds (triceps, subscapular, supraspinale, medial calf)	Harpenden calliper (Galaxy)	Millimetre (mm)
Two bone breadths (biepicondylar humerus and femur)	Sliding calliper (Cescorph)	Centimetre (cm)
Two limb girths (arm flexed and tensed, calf)	Anthropometric tape (Cescorph)	Centimetre (cm)

Training routine

The training program was delivered within the school's ongoing athletic development curriculum and supervised by certified judo coaches. All participating athletes were resident students, and the training regimen generally followed the institution's established pedagogical framework. The program consisted of five sessions per week, with each session lasting approximately 3 hours (15 hours/week total), and typically included warm-up, uchi-komi, randori, ne-waza practice and cool-down activities. Training intensity was monitored using heart rate and RPE, with randori sessions generally aimed at a moderate-to-hard effort level. The competition calendar included several National-level events each year, and tapering periods were introduced before competitions by reducing training volume. The overall program followed a broad macrocycle structure with preparatory, competitive and transition phases. Attendance was recorded regularly, and compliance was generally high. The researchers did not modify the training plan and observed the program as it was implemented by the school's coaching staff.

Statistical methods

Linear mixed-effects models (LMMs) were fitted using the MIXED procedure in SPSS version 17, with Phase included as a fixed effect and Participant ID entered as a random intercept. Parameters were estimated using restricted maximum likelihood (REML), and a first-order autoregressive [AR (1)] covariance structure was specified for the repeated measures. Model assumptions were assessed through visual inspection of standardized residual plots and normal Q–Q plots, which supported homoscedasticity and an approximately normal distribution of residuals. No data were missing across the five assessment phases, resulting in complete observations for all 93 participants at every time point. The statistical significance of the Phase effect for each dependent variable was evaluated using Type III tests of fixed effects, with the significance threshold set at $\alpha=0.05$.

Results

In this section, the results of the current study are presented.

As shown in Table 2, descriptive statistics for height, body mass, fat-free mass and endomorphy, mesomorphy and ectomorphy attributes of the participants were presented over the course of the five training Phases. The height of the boys shows a gradual increase from 153.25±13.75 cm at Phase 0 (initial observation) to 157.56±4.98 cm at Phase 4. Similarly, body mass increases steadily from 45.78±16.26 kg to 56.23±7.44 kg over the 24-month period. Fat-free mass also rose from 38.05±7.26 kg in Phase 0 to 49.68±6.98 kg in Phase 4. In terms of somatotype components, the endomorphy fluctuated throughout the Phases, ranging from 2.0 to 3.6. Mesomorphy showed an overall increase from 4.6±2.8 and reached 5.3±1.9 by Phase 4. However, ectomorphy fluctuated between 5.4 ± 1.8 at Phase 0 to 4.2±1.4 at Phase 4.

Table 2. Height, body mass, fat-free mass, and somatotype components across five phases

Phase	Height Mean±SD (cm)	Body mass Mean±SD (kg)	Fat free mass Mean±SD (kg)	Endomorphy Mean±SD	Mesomorphy Mean±SD	Ectomorphy Mean±SD
Phase 0	153.25±13.75	45.78±16.26	38.05±7.26	2.7±1.3	4.6±2.8	5.4±1.8
Phase 1	156.55±11.1	48.33±14.2	41.26±3.67	3.1±1.8	3.7±2.9	4.7±2.5
Phase 2	156.97±5.28	50.43±12.6	42.56±4.54	2.2±1.2	4.8±1.6	3.3±1.4
Phase 3	157.28±6.78	53.61±5.53	45.04±6.95	3.6±1.9	4.8±1.1	4.0±0.9
Phase 4	157.56±4.98	56.23±7.44	49.68±6.98	2.0±1.2	5.3±1.9	4.2±1.4

In the Figure 1 the changes of the somatotypes in the different Phases are illustrated. In the initial Phase (Phase 0), somatotypes are distributed in the different zones. In Phase 1, somatotypes are shifted towards the ectomorphic zone. During Phase 2, most of the body types started to shift towards the mesomorphic dominant zones. By Phases 3 and 4, participants were clearly positioned in the mesomorphic dominant zone.

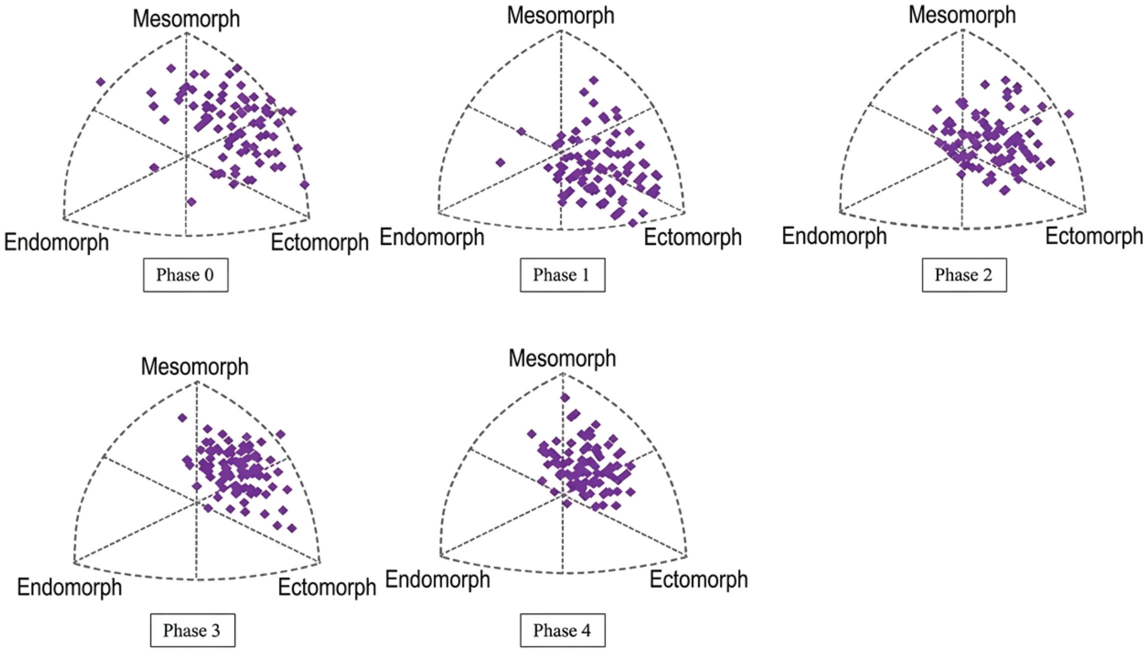

Figure 1. Somato-chart of the participants after each Phase of the observation

In the Table 3, the phase wise mean values and p values from linear mixed model analyses for all anthropometric variables were presented. For the four skinfold sites (biceps, triceps, subscapular, supra spinale), no significant phase effects were observed (all $p \geq 0.23$), indicating that subcutaneous fat at these regions remained statistically stable throughout the 24 month training period despite minor fluctuations in mean values. Notably, the mid calf skinfold showed a significant overall increase ($p<0.001$), driven by a marked rise from 6.07 mm at Phase 3 to 9.00 mm at Phase 4. All girth and skeletal breadth variables increased significantly: arm girth ($p=0.003$) rose progressively from 23.90 cm to 28.91 cm, calf girth ($p=0.012$) increased from 29.28 cm to 35.51 cm, biepicondylar humerus breadth ($p=0.035$) expanded from 5.26 cm to 7.06 cm, and biepicondylar femur breadth ($p<0.001$) increased from 6.68 cm to 9.76 cm. Fat free mass (FFM) demonstrated the most consistent linear increase ($p<0.001$), rising from 38.69 kg at baseline to 49.96 kg at 24 months.

Table 3. Longitudinal changes in anthropometric variables across five phases

Anthropometric variable	Phase 0 mean	Phase 1 mean	Phase 2 mean	Phase 3 mean	Phase 4 mean	p-value
Biceps skinfold (mm)	3.71	4.21	4.05	3.68	4.84	0.236
Triceps skinfold (mm)	6.85	6.50	7.42	6.47	5.77	0.508
Subscapular skinfold (mm)	8.21	7.42	8.07	7.71	7.70	0.938
Supra-spinale skinfold (mm)	4.92	4.85	5.40	6.08	5.79	0.491
Mid-calf skinfold (mm)	6.42	5.64	6.61	6.07	9.00	<0.001
Arm girth (cm)	23.9	24.36	25.63	26.62	28.90	0.003
Calf girth (cm)	29.27	31.50	32.35	33.60	35.50	0.012
Biepicondylar humerus breadth (cm)	5.25	5.97	6.28	6.57	7.06	0.035
Biepicondylar femur breadth (cm)	6.67	8.44	8.92	9.40	9.75	<0.001
Fat-free mass (kg)	38.68	40.82	42.86	45.99	49.95	<0.001

* Significance at 0.05 level

Discussion

The principal finding of this two-year longitudinal study was that youth judo practitioners (aged 12–14 years) undergoing systematic training demonstrated a favourable shift in body composition and somatotype profile. Fat-free mass, limb girths, and skeletal breadths increased significantly, while subcutaneous fat at most sites remained stable. The somatotype distribution shifted progressively from an initial ectomorphic mesomorphic balance toward a clearly mesomorphic dominant profile by the end of the 24 month period. This pattern indicated that, within the context of normal adolescent growth, structured judo training was associated with a more muscular and structurally robust phenotype. These characteristics are widely considered advantageous for judo performance (Noh et al., 2014; Roklicer et al., 2020).

It was important to acknowledge that the observed changes occurred during a critical developmental window (ages 12–14 years), when boys typically experienced a pubertal growth spurt accompanied by significant increases in lean mass, bone dimensions, and body mass (Buśko et al., 2017). In non athletic populations, annual fat free mass gains of approximately 2–4 kg were expected during this period. In the present study, the values were higher than this interval. Fat-free mass rose from 38.69 kg to 49.96 kg over 24 months, which equates to an increase of roughly 5.6 kg per year. This suggested that the combination of normal growth and systematic judo training provided an additive stimulus beyond what would be expected from maturation alone. The stability of skinfold thickness at the biceps, triceps, subscapular, and supra spinale sites (all $p>0.05$) was also noteworthy. In typical adolescent populations, skinfold thickness often increased during puberty due to natural fat accretion (Cordova et al., 2013). The fact that participants of this study maintained stable subcutaneous fat while simultaneously gaining substantial lean mass suggested that the energy cost of judo training was very high. This training involved high-intensity intermittent activity, repeated throws, and combat drills, which likely offset the expected adolescent fat gain (Cordova et al., 2013). This interpretation was consistent with the observation that physically active adolescents often maintained or reduced percent body fat during pubertal development (De Moraes Ferrari et al., 2015b).

The mid calf skinfold, however, deviated from this pattern. The marked rise observed in Phase 4 (from 6.07 mm to 9.00 mm) required further attention. This site-specific adaptation may have been driven by localized biomechanical loading, as the calf muscles (especially the gastrocnemius) were intensively engaged during judo-specific footwork, balance drills, and repeated jumping movements (Alahmadi, 2021). This finding, though statistically robust ($F=8.862$, $p<0.001$), should have been interpreted cautiously and merited verification in future studies with more frequent measurement intervals and dietary tracking (Branco et al., 2022).

The significant increases in arm and calf girths, biepicondylar breadths, and fat free mass were consistent with the dual contribution of growth and training. During the 12–14-year age window, bone dimensions and lean mass typically expanded due to pubertal hormonal changes. However, the extent of the improvements observed especially the 29% rise in FFM surpassed what would normally be expected for this age group. This suggested that judo training offered an additional stimulus for musculoskeletal development, in line with the results reported by Detanico et al. (2020) and Giudicelli et al. (2021). They reported that somatic maturation, body size, and training experience were important contributors to anthropometric and performance-related development in young judo athletes, which supports interpreting the present findings within a combined growth-and-training context (Detanico et al., 2020b; Giudicelli et al., 2020b).

Few longitudinal studies had tracked somatotype changes in youth judo practitioners over an extended period. Our findings aligned with those of Giudicelli et al. (2021), who demonstrated that young male judo athletes progressively developed mesomorphic characteristics with increasing training experience and biological maturation. Similarly, Prieske et al. (2020) reported seasonal improvements in body composition and physical fitness among sub elite youth judokas, with lean mass increases accompanied by stable or reduced body fat patterns consistent with our observations (Prieske et al., 2020b). In contrast, cross-sectional investigations (Drapsin et al., 2020b; Roklicer et al., 2020) have delineated distinct somatotype profiles across weight categories in elite adult judokas; however, by design, these studies were unable to characterize the developmental trajectories that we identified. Our longitudinal data filled this gap by showing that young athletes did not simply arrive at a mesomorphic profile they transitioned toward it over time through the combined effects of growth and sustained training. This supported the contention by Detanico et al. (2020) that training experience, in conjunction with maturation, drove favourable anthropometric adaptations.

The magnitude of fat free mass gains in our cohort was comparable to that reported by Busko et al. (2017), who found that Polish judo athletes had significantly higher FFM than untrained peers. However, our study extended this by demonstrating that this advantage developed progressively during adolescence, reinforcing the value of early and sustained sport specific training within the context of normal growth.

These findings had several practical implications for coaches and sport scientists working with youth judo athletes. Anthropometric monitoring using simple, non invasive measures (skinfolds, girths, bone breadths) could effectively track developmental progress. The progressive increases in FFM and girths observed in this study provided benchmark values for 12–14 year old male judokas undergoing systematic training (Table 3), even in the absence of maturity indicators.

The stability of upper body and trunk skinfolds, combined with increasing lean mass, suggested that body composition was a more sensitive indicator of training adaptation than body mass alone. Coaches should therefore have prioritised FFM and girth measurements over simple weight monitoring. The mid calf skinfold deserved specific attention. Its late increase at 24 months may have signalled the need for periodised nutrition or training load adjustment to avoid unintended fat accretion at specific sites (Casals et al., 2016; Demirci et al., 2023). Alternatively, it might have been a harmless site specific response to biomechanical loading. A regular monitoring would help to distinguish between adaptive and concerning changes. The shift toward a mesomorphic somatotype by Phase 4 suggested that long term athlete development pathways should incorporate somatotype tracking. Athletes who failed to show progressive mesomorphic development during this developmental window might have benefited from supplemental strength or conditioning interventions (Branco et al., 2022).

There were some obvious limitations to this research that need to be acknowledged. Firstly, the sample size (N=93) was moderate for longitudinal modelling, larger multi-centre studies would improve generalisability. The second limitation was that the current analysis does not take into consideration the participants' somatic maturation status (skeletal age/Tanner stage). As somatic maturation status varies significantly among adolescents of the same chronological age, it could impact on their growth rates in terms of both anthropometry and lean mass (Sterkowicz-Przybycień et al., 2012). It would therefore be beneficial for researchers to include assessments of maturity status in their analyses when examining changes due to training vs. changes due to maturational development (Giudicelli et al., 2021; Uchoa et al., 2020).

Conclusions

The current study provided evidence that structured and sustained judo training over a two-year period can produce meaningful changes in the somatotype profiles and anthropometric characteristics among youth judo practitioners. Specifically, the study found a shift toward mesomorphy, with statistically significant increases in flexed arm circumference calf circumference, biepicondylar breadth of the humerus, biepicondylar breadth of the femur and fat-free mass. Moreover, the principal conclusion can be drawn from the study was that the somatic development of youth judo athletes changed in a manner that became progressively more aligned with the specific morphological demands of the sport. The findings also highlighted that these adaptations could be systematically monitored across multiple assessment time points rather than at a single measurement occasion. Practically, it provides coaches and practitioners with a comprehensive basis for using anthropometric monitoring in long-term athlete development. Future research should include maturity indicators, sport-specific performance measures and larger longitudinal samples to better interpret developmental change and further support evidence-based practice in youth judo.

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Conflicts of interest

Authors declare that there is no conflict of interest for submission and publication of this study.

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