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Original article

ANTHROPOMETRIC, SOMATOTYPE AND PHYSICAL FITNESS PROFILE OF THAI ACADEMY ROAD RACE MOTORCYCLISTS

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ABSTRACT

The aim of this study was to profile the anthropometrical and functional characteristics of Thai academy road-race motorcyclists. A total of 12 academy motorcyclists (aged 13-18 yrs) and an aged-matched reference group of high school students were recruited to take part in this study. Anthropometric measures including standing stature, body mass, body mass index (BMI), triceps, subscapular and suprailliac skinfold thickness, and somatotype were recorded. Functional indices of muscle strength (handgrip), muscle endurance, (push-up and partial curl-up), muscle power (countermovement jump; CMJ), flexibility (sit-and-reach-test), and aerobic capacity were also measured. In addition, isokinetic peak torque was measured at angular velocities of 60 and 120 deg/sec to assess lumbar, shoulder and wrist strength, respectively. The academy motorcyclists had markedly greater lumbar and wrist peak torque in flexion and extension movements at both 60 and 120 deg/sec compared with the reference group ($P<0.05$). Left shoulder peak torque was also greater at 60 deg/sec^{-1} in the academy group in both abduction and adduction movements ($P<0.05$) and at 120 deg/sec^{-1} for left shoulder abduction ($P=0.017$). Functional measures indicated that the academy riders possessed greater partial curl-up ($P<0.001$) and press-up ($P<0.001$) muscular endurance and had a higher CMJ ($P<0.001$). Anthropometric measures showed no between-group differences for height, body mass or BMI (all $P>0.05$), however academy riders had lower skinfold measures at all measurement sites ($P<0.05$). Somatotype (balanced) was similar between groups ($P=0.068$), however greater endomorphy was noted in the reference group ($P=0.020$). **Conclusion**: The data can provide a useful reference for the long-term athletic development of academy-aged motorcyclists, or may be used for talent identification purposes.

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KEY WORDS: Academy/ Motorcyclist/ Anthropometric/ Somatotype

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INTRODUCTION

Since its establishment as a world-level competition series in 1949, road race motorcycling has evolved globally to encompass prestigious events such as the Grand Prix (GP) and Superbike World Championships[1]. The growing interest in the sport has seen gate attendances rise to approximately 2.4 million spectators per season, accompanied by a global television audience of ~460 million viewers[1]. Competitions feature major motorcycle manufacturers competing with the latest prototype or commercial production model motorcycles, with success in these events believed to positively influence a manufacturer's global sales of road bikes. The pivotal role of the motorcyclist in promoting a manufacturer's race achievements and business interests has led to the emergence of manufacturer rider academies, focused on identifying young talent in the field.

In order for motorbike manufacturers to invest long-term in young rider talent, the identification of key anthropometric and physiological traits serve as valuable indicators for talent identification[2,3] and recruitment of candidates onto rider academy programs. These traits act as benchmarks to guide the development of tailored strength and conditioning programs for aspiring riders[3,4] based on the determination of a suitable physique[2]. However, to date, research has largely focused on the technological advances of motorbikes and riding equipment[3], with less attention being directed towards identifying the anthropometric and physiological profiles of riders[1,5,6]. Despite the limited available research, Sánchez-Muñoz et al[3] compared elite young Spanish road-race motorcyclists (age: 15.6 years) affiliated with a Red Bull MotoGP Rookies Programme to age-matched physically active male adolescents. It was reported that riders were significantly smaller and lighter, with lower body mass index (BMI), percent body fat (%BF), and muscle mass compared to a reference group. There were also differences in somatotype components, with motorcyclists being described as possessing a mesomorphic-ectomorphic profile. Moreover, riders were documented to possess markedly greater handgrip and lumbar isometric strength.

While Sánchez-Muñoz et al's[3] study provides an important reference point for talent identification and training of young aspiring motorcyclists, only motorcyclists of Caucasian origin were studied. It is documented that the anthropometric and physiological characteristics of individuals from different ethnic backgrounds exhibit distinct physical profiles due to genetic, nutritional and environmental factors[7]. Therefore, it is important to record the characteristics of adolescent motorcyclists from other ethnic origins where manufacturer rider academies have become established, such as in Thailand. Ultimately, this will provide valuable insights that enhance the effectiveness of talent identification programs and performance outcomes[2].

Accordingly, the aim of this study was to (1) describe the anthropometric, somatotype and physical fitness profile of young Thai road race motorcyclists who were currently enrolled onto a motorcycling academy programme, and (2) compare these characteristics against an aged-matched reference group. We hypothesized that there would be a significant difference in anthropometric indices and somatotype components between the motorcyclist academy riders (MOTO) and the age-matched reference group (REF), with significant differences also exhibited across physical fitness tests.

METHODS

Participants: Twelve Thai academy road race motorcyclists and 12 aged-matched high-school participants free from cardiovascular, respiratory, and metabolic diseases were recruited to take part in this study (see Table 1 for demographic data). The sample size was determined based on a sensitivity analysis using G-power software[8]. It was estimated that an independent t-test design with 12 participants per group, achieving 80% power (α = 0.05), would be sensitive to effects of d =1.2. Inclusion criteria for the MOTO group required participants to be affiliated to a single factory-based motorcycle academy team and have >1 year competition experience. For the REF group, inclusion criteria were being physically active for $\geq$60 min•day^{-1} for $\geq$3 day•wk^{-1}. Participants were familiarized with the experimental procedures and associated risks and voluntary written informed consent was obtained from the participants and parents/guardian. The study was approved by the local Ethics Committee for Human Research at Mahidol University (COA No. MU-CIRB 2022/030.1702).

Procedure: A matched-group research design was employed for this cross-sectional-observational study. The participants were requested to visit the laboratory on three separate occasions at the same time of day (9.00 am) for experimental testing. Participants were asked to abstain from alcohol and caffeine for 24 hours, and not to exercise 24 h prior to arrival at the laboratory. On the first visit, participants were familiarized with all experimental test procedures. On the participants second visit, participants changed into shorts and a t-shirt and had their anthropometric measures recorded following the Carter and Heath method[9]. Individual somatotypes were subsequently calculated. On the third visit, following a 5-minute standardized warm-up on a cycle ergometer and dynamic stretches, functional measures were completed in the following order, sit-and-reach test, countermovement jump (CMJ), handgrip and Isokinetic dynamometer strength tests, pushup and curl-up muscle endurance tests, and maximal aerobic capacity test ($\dot{V}O_{2peak}$).

Anthropometric measures

Stature and body mass: The standing height of the participants was recorded using a stadiometer (Krotron, model HAS, Thailand) to the nearest 0.1 cm. The participants were instructed to stand straight with their back of the head and heels in contact with the stadiometer. The head was positioned in the Frankfort horizontal plane, ensuring the line from the bottom of the eye socket to the top of the ear was parallel to the floor. The participants were asked to take a deep breath while stretching upward (i.e., stretch stature) and the headboard was lowered until it touched the vertex[9]. Body mass was measured using digital scales (Omron HBF-362, Japan) and recorded to the nearest 0.1 kg. Body mass index (BMI) was subsequently calculated using the formula: BMI = Body mass (kg) / Height (m)^2.

Bicep (Elbow Flexion) and Calf Circumference: Bicep circumference (girth) was measured by asking the participant to flex their right shoulder to 90° and elbow to 45°, while clenching their hand and maximally contracting the elbow flexors and extensors (i.e., flexed and tensed). The greatest girth of the arm was subsequently recorded using a tape measure (Cescorf, Porto Alegre, Brazil) to the nearest 0.1 mm[9]. Calf circumference was recorded with the participant standing feet slightly apart. A tape measure was placed around the calf at the site of maximal circumference and recorded to the nearest 0.1 mm[9].

Humerus and Femur Breadths: The biepicondylar breadth of the humerus of the right arm was measured by placing sliding calipers (Harpenden anthropometer, Holtain U.K.) on the medial and lateral epicondyles of the humerus while the shoulder and elbow were flexed to 90°[9]. The biepicondylar breadth of the femur of the right leg was recorded with the participant seated and the leg bent at a 90° angle. The calipers were placed at the greatest distance between the lateral and medial epicondyles of the femur[9].

Skinfolds thickness: Skinfold measures were marked and measured by using the thumb and forefinger to firmly pinch and lift a fold of skin and underlying subcutaneous tissue away from the muscle at the designated sites. The jaw edges of the caliper (Harpenden, HAB International; Southam, UK) were placed ~1 cm below the fingers while allowing the calipers to apply full pressure. After a duration of ~2 seconds, skinfold thickness was recorded to the nearest 0.1 mm. All measures were taken on the same side of the body while the participant remained relaxed during measurements. The skinfold measures were duplicated and the average of the two measures were used in data analyses. Skinfold measures were recorded at selected sites in accordance with Carter and Heath[9] recommendations as follows:

Subscapular Skinfold: The subscapular skinfold was raised on a line from the inferior angle of the scapula and obliquely downwards and 45° laterally (i.e., diagonally).

Suprailiac (Supraspinale) Skinfold: The fold was lifted 5-7 cm above the anterior superior iliac spine on a line to the anterior axillary border. The fold was diagonal descending medially at a 45° angle.

Triceps Skinfold: In the anatomical position with the participants arms hanging freely, a fold on the back of the arm was raised at the point halfway on a line between the acromion and olecranon processes.

Calf Skinfold: In a seated position with the leg bent at a 90° angle, a vertical skinfold on the medial side of the leg was raised at the position of the maximum girth of the calf.

Somatotype:

Somatotype was determined according to the Carter and Heath anthropometric method[9]. Somatotyping uses 3 numbers for providing a meaningful interpretation of body shape and it is recommended that the somatotype attitudinal mean (SAM) is used for statistical analysis[9]. The SAM refers to the average somatotype attitudinal distance (SAD, which is the distance in three dimensions between any two somatopoints) and is calculated in component units). The within-group SAD was calculated comparing each participants' somatotype to the mean somatotype of the same group (Equation 1). The between-group SAD was calculated by comparing each participants' somatotype in one group to the mean somatotype of the other group to provide a measure of dissimilarity between groups (Equation 2). The SAM represents the average SAD of a group and was used for statistical analysis (Equation 3).

Equation 1 (Within-group SAD):

$$SAD_{i,mean} = \sqrt{(ENDO_i - ENDO_{mean})^2 + (MESO_i - MESO_{mean})^2 + (ECTO_i - ECTO_{mean})^2}$$

Where: $SAD_{i,}mean$ = the somatotype attitudinal distance between participant $_i$ and the mean somatotype of their own group.

Equation 2 (Between-group SAD):

$$SAD_{A;B} = \sqrt{(ENDO_A - ENDO_{mean}B)^2 + (MESO_A - MESO_{mean}B)^2 + (ECTO_A - ECTO_{mean}B)^2}$$

Where: $SAD_{A;;B}$ = the somatotype attitudinal distance between a participant in Group A (MOTO) and the mean somatotype of Group B (REF);

Where: $ENDO_A$, $MESO_A$, and $ECTO_A$ = somatotype components of a participant in Group A (MOTO).

Where: $ENDO_{mean,B}$, $MESO_{mean,B}$, and $ECTO_{mean,B}$ = mean somatotype components of Group B (REF).

Equation 3:

$$SAM = \sum SAD_i / n_X$$

Where: SAD_i = somatotype of each participant minus the mean somatotype of the group; n_X is the number in the group x.

Functional testing

Sit-and Reach-Test: Participants sat with their legs outstretched and feet touching the testing box before sliding forwards with their dominant hand placed on top of the other hand. Three trials separated by a 30 second recovery period were performed and the best score in cm was recorded[10]

Countermovement Jump (CMJ): Each participant stood on a portable jump mat (JumpMat Pro, Northern Ireland, U.K.) with their arms by their sides, and jumped as high as possible using an arm swing. The jump height was recorded using an iOS application (FSL Scoreboards, U.K.). A total of 3 jumps separated by a 1-minute recovery period were completed. The highest jump, recorded to the nearest 0.1 cm, was used for data analyses.

Handgrip Strength: Participants completed a standardized warm-up consisting of two familiarization trials with a portable Hand Grip Strength Dynamometer (Takei A5401, Niigata, Japan). In a seated position, the right shoulder was abducted, and the elbow was flexed at a 90° angle, while the forearm and wrist were maintained in a neutral position[11]. Three maximal contractions were performed for 5 seconds each on the right hand, with a 1-minute recovery period between trials. The highest recorded value in kilograms (kg) among the three trials was considered as the participant's maximal handgrip strength. Visual feedback regarding the recorded strength was provided during the assessment.

Isokinetic dynamometer strength tests:
All isokinetic tests were conducted using an isokinetic dynamometer (Biodex System 4 Pro, Biodex Corporation, Shirley, NY, USA) with gravity corrections applied, and verbal encouragement provided.

Trunk: Participants were positioned seated upright on the dual-position back extension-flexion attachment, with hips and knees flexed at 90°, thighs parallel to the floor, and the dynamometer axis aligned with the anterior superior iliac spines. The trunk range of motion was set to 50° (-30° flexion to 20° extension)[12]. Participants completed a warm-up of 10 submaximal trunk flexion-extension movements at 120 deg/sec^{-1} before performing 5 maximal isokinetic trunk flexion-extension (concentric-concentric) repetitions at 60 deg/sec^{-1} and 120 deg/sec^{-1}. Participants were instructed to keep hands crossed over their chest and to exert their maximal effort during the protocol and peak torque was recorded.

Shoulder horizontal adduction and abduction: Participants were positioned supine on the dynamometer with straps securing the thorax and waist[13]. respectively. A single set of 5 maximal repetitions was performed at 60 deg/sec^{-1} and 120 deg/sec^{-1} for each arm, with peak torque recorded.

Wrist: A custom designed attachment was used to measure wrist flexion and extension peak torque at 60 deg/sec^{-1} and 120 deg/sec^{-1} angular velocities. Participants sat in an upright position on a bench with their right elbow next to their torso and flexed at a 90° angle, and performed wrist extension and flexion (concentric-concentric) through a maximum range of motion. A single set of 5 repetitions were performed at each angular velocity for the right arm (throttle hand) only, and peak torque was recorded.

Muscle Endurance: A partial curl-up test was used to assess the local muscle endurance of the abdominal muscles. Following a similar protocol to National Strength and Conditioning Guidelines (NSCA) guidelines[14], participants assumed a supine position with legs bent to a 90° angle. The arms were placed on the floor next the participants body, with the fingers touching a 10 cm piece of masking tape positioned perpendicular to the fingers on the floor. Another piece of masking tape was placed 12 cm in front and parallel of the first tape marker (second marker). The participants were asked to perform curl-ups in time with a metronome set to cadence of 40 beats•min^{-1}. Each participant was required to lift their shoulders off the floor in time with the metronome and touch the second marker, before allowing their upper back to touch the floor before the following curl-up. The athlete performed as many curl-ups as possible without pausing up to a maximum of 40 repetitions.

A push-up test was employed to assess upper body muscle endurance. Participants assumed a push-up start position by placing their hands shoulder width apart with their elbows and body straight, with feet positioned together. Participants were then asked to lower their body to the ground until their chest touched the researcher's vertical fist placed on the ground[14]. The participants were asked to complete as many repetitions as possible (continuously) until reaching a maximum of 40 or reaching failure.

Maximal Aerobic Capacity ($\dot{V}O_{2peak}$)*:* An incremental cycle ergometer test with online breath-by-breath measures of oxygen uptake (Cortex Metalyzer, Leipzig, Germany) was used for the assessment of $\dot{V}O_{2peak}$. The test started with a 5 min warm-up at 75 W using a cycle ergometer attached to a power meter (Cyclus 2, Leipzig, Germany). The power output was then increased incrementally by 25 W every 2 min until the attainment of volitional exhaustion[28, 29]; indicated by not being able to sustain a cadence of 60-70 rpm or demonstrated using established criteria for attaining $\dot{V}O_{2max}$ as follows; 1) A plateau in $\dot{V}O_2$ or failure to increase $\dot{V}O_2$ by 150 $mL.min^{-1}$ with an increased workload, 2) HR_{max} within 5 bpm of age-predicted HR (220-age), 3) RER ≥ 1.10, and 4) RPE at peak exercise > 17 on the 6-20 scale [30,31]. Oxygen uptake, RPE, and heart rate (Polar, Finland) was recorded in the last 30 sec of each stage. $\dot{V}O_{2peak}$ (used interchangeably $\dot{V}O_{2max}$) with was averaged over the last 30 sec of the final stage before cessation of exercise and was expressed in relative terms ($ml{\cdot}kg^{-1}{\cdot}min^{-1}$).

DATA ANALYSES

Descriptive statistics (mean ± SD, range) were used to summarize participant characteristics across all parameters. Group comparisons were assessed for normality using the Shapiro-Wilk test and visual inspection of Quantile-Quantile (Q-Q) plots. If the data were normally distributed, Welch's independent *t* tests (two-tailed) were employed to examine differences between groups (stature, body mass, BMI, limb circumference, bone breadths, triceps, subscapular, and suprailiac skinfolds, somatotype components, functional measures, isokinetic measures). For non-normally distributed data, Mann-Whitney U tests were performed (SAM, calf skinfold). A one-sample t-test was used for both the push-up and curl-up tests due to zero SD (i.e., all participants achieved maximum number of repetitions). The mean difference and 95% confidence intervals (95% CI) are reported for all indices. The α-level of statistical significance was set at $P<0.05$. Cohen's d effect sizes were calculated to determine the magnitude of difference between groups, and assessed against Cohen's benchmarks: 0.2 = small, 0.5 = moderate, and 0.8 = large effects[16]. For non-normally distributed variables, the rank biserial correlation (r_{rb}) was used to determine the magnitude of difference between groups, with <0.1 = very small, <0.2 = small, <0.3 = medium, <0.4 = large, >0.4 = very large effects[17]. All statistical analyses were performed using Jamovi statistical software (The jamovi project, 2024)[32].

RESULTS

Anthropometric Measures

Stature, body mass and BMI: Standing stature (mean difference =1.3 cm, 95% CI [-6.47, 8.97], P = 0.740, d = 0.14; Table 1) and body mass was not significantly different between the REF and MOTO groups. Similarly, no significant difference in BMI was noted between groups (mean difference = 1.5 kg·m^2, 95% CI [-1.5, 4.5], *P* = 0.313, *d* = 0.43; Table 1).

Limb Circumference and Bone Breadths: Flexed bicep circumference (mean difference = -0.9 cm, 95% CI [-3.8, 1.9], *P* = 0.503, *d* = -0.28; Table 1) and calf circumference (mean difference = 0.2 cm, 95% CI [-2.3, 2,7], *P* = 0.846, *d* = 0.08; Table 1) were similar between groups. Bone breadths at the humerus (mean difference = -0.04 cm, 95% CI [-0.45, 0.37], *P* = 0.834, *d* = -0.09; Table 1) and femur (mean difference = 0.17 cm, 95% CI [-0.47, 0.81], *P* = 0.590, *d* = 0.22; Table 1) were also not different between groups.

Skinfold thickness: A significantly higher skinfold thickness was recorded in the REF group at the triceps (mean difference = 6.29 mm, 95% CI [1.6, 10.9], *P* = 0.011, *d* = 1.18; Table 1), subscapular (mean difference = 5.46 mm, 95% CI [0.8, 10.1], *P* = 0.024, *d* = 1.03; Table 4.1), suprailiac (mean difference = 7.33 mm, 95% CI [1.6, 13.1], *P* = 0.015, *d* = 1.10; Table 1), and calf (mean difference = 5.0 mm, 95% CI [1,0, 8.5], *P* = 0.006, r_{rb} = 0.66; Table 1) measurement sites compared with skinfold measures taken in the MOTO group.

Somatotype: The somatotype attitudinal mean (SAM) score was not significantly different between groups (mean difference = 0.80 a.u., 95% CI [0.1, 1.7], *P* = 0.068, r_{rb} = -0.44). The within-group SAM score indicating variation within each group (Table 1). There was no significant difference in ectomorphy (mean difference = -0.33 a.u., 95% CI [-1.5, 0.8], *P* = 0.546, *d* = -0.25; Table 1) or mesomorphy (mean difference = -0.37 a.u., 95% CI [-1.2, 0.5], *P* = 0.359, *d* = -0.38; Table 1) components between the REF and MOTO groups. However, a significant lower endomorphy was noted in the MOTO group (mean difference = 1.5 a.u., 95% CI [0.3, 2.7], *P* = 0.020, *d* = 1.04; Table 1). Figure 1 illustrates the individual somatotypes of the MOTO and REF participants.

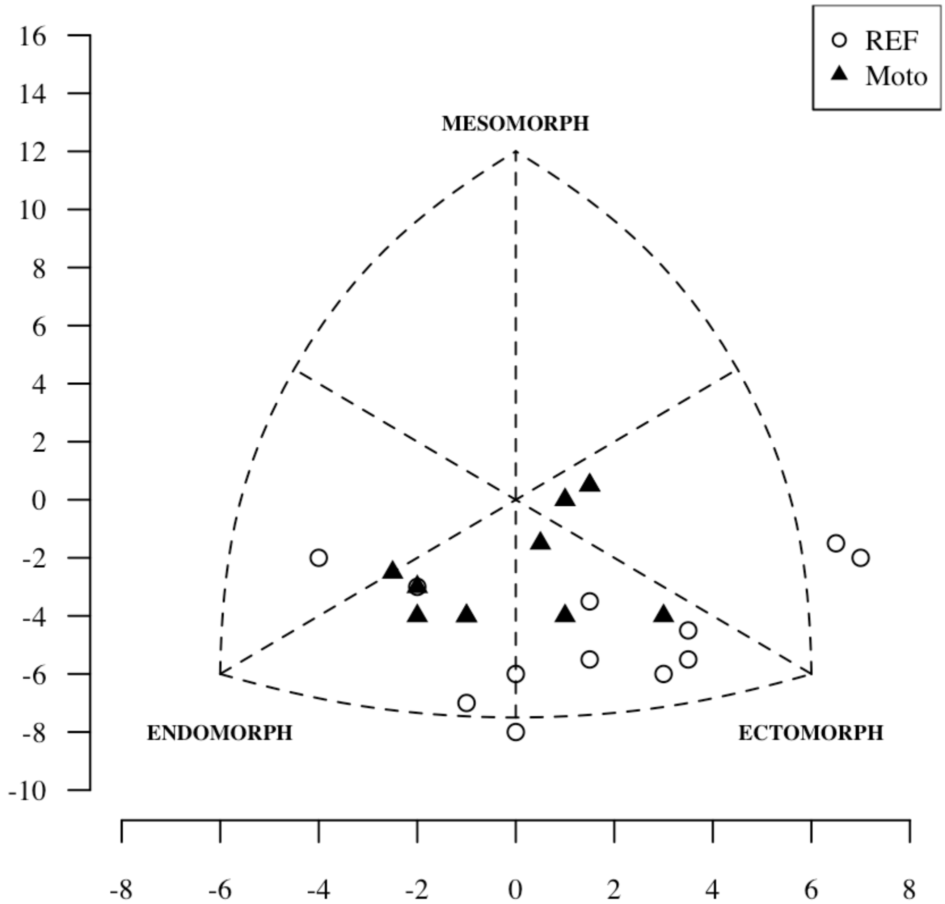

Figure 1. Somatoplot of motorcyclists (MOTO, triangles) and age-matched reference group (REF, open circles). X and Y axis scale represent somatotype component numbers for endomorphy, mesomorphy, and ectomorphy.

Functional Measures

VO_{2peak} was similar between the REF and MOTO groups (mean difference = -3.0 ml·kg·min^{-1}, 95% CI [-8.5, 2.5], P = 0.271, d = -0.46; Table 1). Handgrip strength (mean difference = -4.3 kg, 95% CI [-11.3, 2.6], P = 0.206, d = -0.53; Table 1) and sit-and-reach test distances were also similar between groups (mean difference = -0.2 cm, 95% CI [-5.9, 5.6], P = 0.953, d = -0.02; Table 1). However, the REF group recorded significantly lower CMJ heights compared with MOTO (mean difference = -6.9 cm, 95% CI [-10.9, -2.9], P = 0.002, d = -1.47; Table 1). The REF group also performed a significantly lower number of repetitions for the push-up test (mean difference = -21 repetitions, 95% CI [-26.0, -17.0], P <0.001, d = -3.13; Table 1) and curl-up test (mean difference = -14.0 repetitions, 95% CI [-18.0, -9.0], P<0.001, d = -2.11; Table 1).

Isokinetic Measures

Trunk Strength: Trunk rotational force at 60°·sec^{-1} was not different between groups during flexion (mean difference = -18.4 N·m, 95% CI [-55.5, 18.8], P = 0.316, d = -0.42; Table 2) or extension (mean difference = -49.9 N·m, 95% CI [-139.0, 39.3], P = 0.259, d = -0.47; Table 2) movements. However, at 120°·sec^{-1}, trunk rotational force was significantly lower in the REF group during both flexion (mean difference = -42.9 N·m, 95% CI [-81.2, -4.6], $P = 0.030$, $d = -0.95$; Table 2) and extension (mean difference = -88.4 N·m, 95% CI [-169.0, -8.01], $P = 0.033$, $d = -0.93$; Table 2) compared with the MOTO group.

Wrist Strength: Wrist rotational force at 60°·sec^{-1} was significantly lower during flexion (mean difference = -1.1 N·m., 95% CI [-1.8, -0.4], $P = 0.003$, $d = -1.34$; Table 2) and extension (mean difference = -1.8 N·m., 95% CI [-2.7, -0.9], $P < 0.001$, $d = -1.67$; Table 2) in the REF compared with the MOTO group. Similarly, at a rotational velocity of 120°·sec^{-1}, a significantly lower force was also recorded in REF during flexion (mean difference = -1.3 N·m., 95% CI [-2.1, -0.6], $P = <0.001$, $d = -1.59$; Table 2) and extension (mean difference = -2.1 N·m., 95% CI [-3.0, -1.2], $P<0.001$, $d = -1.91$; Table 2).

Shoulder Strength: Left shoulder rotational abduction force at 60°·sec^{-1} was significantly lower in the REF compared with the MOTO group (mean difference = -18.0 N.m., 95% CI [-31.5, -4.5], P=0.011, $d = -1.15$; Table 2). However, no between group difference was found in right shoulder at the same speed (mean difference = -10.5 N.m., 95% CI [-26.6, -5.6], P=0.189, $d = -0.57$; Table 2). Similarly, left shoulder rotational abduction force at 120°·sec^{-1} was significantly lower in the REF compared with the MOTO group (mean difference = -15.4 N.m., 95% CI [-27.7, -3.0], P=0.017, $d = -1.08$; Table 2), with no between-group difference noted in the right shoulder at the same isokinetic speed (mean difference = -4.7 N.m., 95% CI [-20.7, 11.4], P=0.551, $d = -0.25$; Table 2). Left shoulder rotational adduction force at 60°·sec^{-1} was significantly lower in the REF compared with the MOTO group (mean difference = -19.0 N.m., 95% CI [-33.3, -4.7], P=0.012, $d = -1.15$; Table 2). In contrast, no significant between-group difference was observed in the right shoulder at the same rotational speed (mean difference = -8.9 N.m., 95% CI [-23.2, 5.5], P=0.214, $d = -0.53$; Table 2). For shoulder rotational adduction force at 120°·sec^{-1}, no significant between group difference was observed in the left (mean difference = -10.9 N.m., 95% CI [-24.8, 2.9], P=0.116, $d = -0.69$; Table 2) or right (mean difference = -13.8 N.m., 95% CI [-29.5, 2.0], P=0.083, $d = -0.76$; Table 2) shoulders, respectively.

Table 1. Anthropometric, somatotype, and functional measures.

Variable	*REF*	*MOTO*
Age (yrs)	15.5 ± 1.6 (13.0-18.0)	15.0 ± 1.6 (13.0-18.0)
Height (cm)	170.0 ± 9.3 (152.0-185.0)	169.0 ± 9.0 (146.0-178.0)
Body mass (kg)	63.8 ± 17.5 (34.0-84.8)	58.0 ± 8.9 (37.0-66.7)
BMI ($kg \cdot m^{-2}$)	21.8 ± 4.4 (14.7-28.7)	20.3 ± 2.0 (17.1-23.4)
Somatotype (a.u)		
Endomorphy	4.6 ± 1.7 (1.5-7.5)	3.1 ± 1.1 (2.0-5.5) *
Mesomorphy	1.5 ± 1.0 (0.5-3.0)	1.9 ± 1.0 (0.5-3.5)
Ectomorphy	3.0 ± 1.7 (0.5-5.5)	3.3 ± 0.9 (2.0-4.5)
SAM	5.6 ± 2.0 (1.6-8.1)	5.5 ± 1.2 (4.4-8.7)
Skinfolds (mm)		
Triceps	16.1 ± 6.8 (7.0-30.0)	9.8 ± 3.3 (5.5-15.0) *
Suprailiac	16.6 ± 8.3 (4.0-29.5)	10.3 ± 4.5 (6.0-21.5) *
Subscapular	14.9 ± 6.9 (5.0-30.5)	9.5 ± 3.0 (6.0-17.5) *
Calf	15.6 ± 6.3 (9.0-26.0)	9.6 ± 2.5 (6.5-14.5) *
Humerus breadth (cm)	4.4 ± 0.6 (3.2-5.3)	4.4 ± 0.4 (3.5-4.8)
Femur breadth (cm)	7.7 ± 0.9 (6.2-9.6)	7.5 ± 0.5 (6.3-8.1)
Calf circumference (cm)	34.4 ± 3.4 (28.5-38.5)	34.2 ± 2.3 (30.0-37.5)
Bicep circumference (flexed)	26.0 ± 4.0 (19.0-31.5)	26.9 ± 2.4 (23.5-30.5)
VO_{2peak} ($ml \cdot kg \cdot min^{-1}$)	49.7 ± 7.1 (40.0-64.0)	52.7 ± 5.9 (46.0-68.0)
Handgrip strength (right) (kg)	33.1 ± 8.9 (14.7-44.3)	37.4 ± 7.4 (23.5-50.1)
CMJ (cm)	29.4 ± 3.3 (25.3-34.2)	36.3 ± 5.7 (29.0-48.8) *
Push-up (No.)	18.7 ± 6.8 (8.0-28.0)	40.0 ± 0.0 (40.0-40.0) *
Curl-up (No.)	26.4 ± 6.4 (18.0-35.0)	40.0 ± 0.0 (40.0-40.0) *
Sit-and-reach (cm)	10.9 ± 7.6 (0.0-21.0)	11.1 ± 5.9 (0.0-20.0)

Mean ± SD (min-max); REF = Reference group; MOTO = Academy Motorcyclist group; SAM = Somatotype Attitudinal Mean (within group); *Indicates significant difference between group (P<0.05).

Table 2. Isokinetic strength measures.

Movement	*REF*		*MOTO*	
	60°·sec^{-1} (N.m.)	*120°·sec^{-1} (N.m.)*	*60°·sec^{-1} (N.m.)*	*120°·sec^{-1} (N.m.)*
Trunk				
Flexion	148.0 ± 48.7	142.0 ± 41.4	148.0 ± 38.3	185.0 ± 48.6 *
Extension	298.0 ± 113.0	256.0 ± 97.6	348.0 ± 96.6	344.0 ± 92.1 *
Wrist				
Flexion	3.6 ± 0.8	3.7 ± 0.9	4.7 ± 0.8 *	5.0 ± 0.8 *
Extension	4.1 ± 0.9	3.9 ± 0.9	5.9 ± 1.2 *	6.9 ± 1.3 *
Shoulder Adduction				
Left	48.4 ± 15.7	50.8 ± 18.3	67.4 ± 17.3 *	61.7 ± 13.4
Right	60.6 ± 15.5	53.7 ± 20.4	69.5 ± 17.4	67.5 ± 15.8
Shoulder Abduction				
Left	49.4 ± 15.9	49.2 ± 14.0	67.4 ± 15.2 *	64.6 ± 14.4 *
Right	59.0 ± 19.7	60.9 ± 22.6	69.5 ± 17.4	65.6 ± 13.7

Mean ± SD; REF = Reference group; MOTO = Academy Motorcyclist group; *indicates significant difference between groups (P<0.05) when comparing against the same movement/velocity.

DISCUSSION

The main findings from this study showed that despite groups having similar stature, body mass, BMI, and somatotype (balanced somatotype), the REF had a significantly higher endomorphy component indicating higher body adiposity. Additionally, there was evidence that MOTO exhibited significantly greater trunk, wrist and shoulder isokinetic strength compared with the REF group, with other functional assessments revealing the academy riders possessed higher muscular endurance capacity and higher lower body power.

While the SAM scores indicated both groups had a relatively high degree of variation in body shape, the REF exhibited an increased endomorphy, with the academy riders having a tendency for a slightly leaner and more muscular physique (Table 1). The observation of higher endomorphy in REF is suggestive of increased body adiposity, and is supported by the higher skinfold measures recorded at the triceps, subscapular, suprailiac, and calf measurement sites (Table 1). Our current findings are in agreement with Sánchez-Muñoz et al[3] who found Spanish elite level motorcyclists (aged 15.6 $\pm$ 1.1 years) to have a significantly lower percentage body fat and higher muscle mass compared with an age-matched reference group. The lower body adiposity in the MOTO group likely reflecting the impact of repetitive bike handling at high speeds and participation in structured training programs.

In contrast to our study, where the motorcyclists did not clearly align with any particular somatotype (i.e., balanced; 3.1-1.9-3.3; Figure 1), Sánchez-Muñoz et al[3] reported elite young motorcyclists to be predominantly mesomorphic, specifically ecto-mesomorphic (2.5-4.4-3.7). The differences in somatotypes observed between our studies may partly be attributed to ethnic origin and/or training regimens. Given that higher lean mass could be advantageous for handling a motorbike and enhancing performance[18,19], sports practitioners working with Thai academy riders might consider increasing muscle mass through targeted strength and conditioning training. Although we did not directly measure muscle mass in our study, the trend towards higher mesomorphy in the MOTO group may explain the motorcyclists displaying significantly greater muscle endurance in the partial curl-up and press-up tests and higher CMJ performance (Table 1). Additionally, similar to our findings, Sánchez-Muñoz et al[3] reported elite youth motorcyclists to have significantly lower endomorphy compared with a reference group, supporting motorcyclists to typically exhibit a leaner body shape. While a lower body mass and size are thought to be important for riding performance, as the rider influences the bikes power-to-weight ratio and accelerative speed[1,3,20,21], we did not observe a difference in body mass between the MOTO and REF groups (Table 1).

A novel aspect of our study was the use of a custom designed attachment to measure wrist flexion and extension strength. Despite similar handgrip dynamometer values between groups (Table 1), a greater isokinetic wrist flexion and extension peak torque was noted at both 60 deg/sec^{-1} and 120 deg/sec^{-1} angular velocities in the MOTO group (Table 2). To our knowledge, there is no available data to directly compare our between-group findings, however in alignment with our, and others[3] handgrip data, the right wrist is used extensively during riding a bike to control the throttle and the front brake[1,3,21]. Accordingly, it can be speculated that the greater peak torque in the MOTO group is due to the extensive use of the forearm muscles during training and competition. Indeed, this is supported by riders reporting forearm pump and requiring surgical intervention to overcome the decrements in rider fatigue[22–24].

Upper limb strength is viewed as important for motorbike handling[3,19]. Trunk flexion (abdominal) and extension (lumbar) peak torque values were greater at an angular velocity of 120 deg/sec^{-1} in the MOTO compared with the REF group (Table 2). The between-group differences in isokinetic trunk strength possibly reflecting the specific demands placed on the trunk muscles during various phases of motorcycling, where counteracting the anterior, posterior, and lateral accelerations to the body plays a significant role[6]. When motorcyclists lean forwards to maintain an aerodynamic position on straights, their trunk muscles must stabilize their body against wind resistance and forces generated by high speed riding[25]. During repeated deaccelerations and cornering, changing forces place a substantial load on the body (6) which likely requires dynamic trunk stabilization to control the bike and navigate turns. We also observed the MOTO group to exhibit greater peak torque value for the left shoulder during 120 deg/sec^{-1} abduction and 60 deg/sec^{-1}adduction movements. In contrast, similar between-group force values were recorded for the right shoulder across the different movements and angular velocities (Table 2). The greater left shoulder strength in the MOTO group may be a consequence of repeatedly maneuvering the bike into corners or keeping the elbows tucked into the side of the body to maintain an aerodynamic body position (i.e., limit drag) when riding at high speed[26]. Whereas the right hand must control the throttle and front brake, the left arm may move more freely to assist with cornering. Alternatively, the aforementioned between-group differences in isokinetic strength measures may be related to MOTO participants performing specific (or general) strength and conditioning exercises to improve rider performance[3].

In the present study, our sample size was based on recruiting academy motorcyclist affiliated with a single bike manufacturer training center in Thailand. Therefore, to extend our current findings, and achieve a more representative sample size, future studies should consider multicenter studies that include motorcyclists from various academy training centers. We also used a convenience sample to select participants in the REF group as opposed to random sampling. This may limit statistical inferences of differences between groups at the population-level. In calculating somatotypes, we omitted collecting additional skinfold measures to provide an assessment of percentage bodyfat (%Bfat)[27], therefore our interpretation of body adiposity are limited to the sites of skinfold measurements which we extrapolated to indicate %Bfat. In future studies, we recommend body impedance analysis (BIA) or dual-energy X-ray absorptiometry (DEXA) be used to analyze the body composition. Finally, another limitation of our study was that we used a 40 maximum repetition press-up and curl-up test, which was achieved by all participants in the MOTO group. Thus, future studies should employ muscle endurance protocols which permit participants to attain maximum number of repetitions to failure.

In conclusion, our findings suggest that Thai academy motorcyclists have lower levels of body adiposity and are less endomorphic compared with an age-matched reference group. Moreover, motorcyclists exhibit greater strength levels in the shoulder, trunk, and wrist at specific isokinetic speeds, and lower body power. Taken together, our findings highlight the need for tailored interventions to manage body composition and develop upper and lower body strength to help coaches and sports practitioners optimize the long-term athlete development of motorcyclists.

CONFLICTS OF INTEREST

The authors declare no conflict of interest

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CODE AVAILABILITY

The code for reproducing the somatoplot is available on the following link:
https://osf.io/mbhn2/?view_only=bfec5cb0c5204a079190bf61629d7cbf

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