Journal of Athletic Enhancement

Review Article

a SciTechnol journal

Musculoskeletal Profile of Amateur Combat Athletes: Body Composition, Muscular Strength and Striking Power

Luke Del Vecchio[1*], Nattai Borges[2], Campbell MacGregor[3], Jarrod D Meerkin[4] and Mike Climstein[5,6]

Abstract

Previous research highlighted positive musculoskeletal adaptations resulting from mechanical forces and loadings distinctive to impacts and movements with sports participation. However, little is known about these adaptations in combat athletes. The aim of this study was to quantify Bone Mineral Density (BMD), Lean Muscle Mass (LMM) and punching and kicking power in amateur male combat athletes. Thirteen male combat athletes (lightweight and middleweight) volunteered all physiological tests including dual energy X-ray absorptiometry for Bone Mineral Density (BMD) segmental body composition (Lean Muscle Mass (LMM)), muscle strength and striking power, sedentary controls (n=15) were used for selected DXA outcome variables. There were significant differences ($p \leq 0.05$) between combat groups for lumbar spine (+5.0%), dominant arm (+4.4%) BMD and dominant and non-dominant leg LM (+21.8% and +22.6%). Controls had significantly ($p<0.05$) high adiposity (+36.8% relative), VAT mass (+69.7%), VAT area (+69.5%), lower total body BMD (-8.4%) and lumbar spine BMD (-13.8%) than controls. No differences in lower limb BMD were seen in combat groups. Arm lean mass differences (dominant vs. non-dominant) were significantly different between combat groups ($p<0.05$, 4.2% vs. 7.3%). There were no differences in punch/kick power (absolute or relative) between combat groups. 5RMstrength (bench and squat) correlated significantly with upper limb striking power (r=.57), dominant and non-dominant leg BMD (r=.67, r=.70, respectively) and total body BMD (r=.59). BMD and LMM appear to be particularly important to discriminate between dominant and non-dominant upper limbs and less so for lower limb dominance in recreational combat athletes.

Keywords

Muscular balance; Mixed martial arts; Bone density; Lean muscle; Punch; Kick

***Corresponding author:** Luke Del Vecchio, School of Health and Human Sciences, Southern Cross University Gold Coast, Queensland Australia; Tel: 07 5589 3202; Email: luke.delvecchio@scu.edu.au

Received: March 03, 2021 **Accepted:** March 18, 2021 **Published:** March 31, 2021

Introduction

The growing interest in combat sports for recreational fitness and amature competition has seen a growth in participant numbers in Mixed-Martial Arts (MMA) and kickboxing over the past decade, with its participation associated with improved health and wellness [1]. Combat sports participation requires athletes to develop progressive levels of technical competence, tactical responsiveness and physical conditioning [2]. Due to the imbalanced bilateral loading patterns inherent within combat sports, combat athletes who fail to build an adequate foundation of physical conditioning may develop musculoskeletal imbalances between limbs [3,4].

Site specific loading patterns of the upper limbs in combat sports have been shown to be associated with improvements in bone health resulting in changes to Bone Mineral Content (BMC), Bone Mineral Density (BMD) and bone geometry [5-8]. In addition to skeletal improvements, research has also highlighted positive muscle and strength adaptations resulting from mechanical forces and loadings distinctive to impacts and movements associated with individual sports participation [9-13]. Musculoskeletal adaptations in combat sports and combat conditioning vary depending on training background, duration and type of physical conditioning and between amature and elite professional participants [5,6,14]. Further complicating adaptations for combat athletes is the natural stance that is adopted which will impact the loading of the upper body and lower body dominant and non-dominant limbs [4,15].

Similar findings have been reported for upper limb variations for BMC, Lean Tissue Mass (LM) and isometric grip strength in tennis players [16,17] and BMD in college baseball athletes [18]. Studies have also demonstrated similar differences in bilateral sports with leg lean mass and unilateral isometric back squat strength differences in male amateur Australian footballers [19], differences in leg BMC and heel raise strength in male cross country skiers [20], lower limb isokinetic muscle strength differences in elite male futsal players [21] and BMD differences in amateur male team based athletes (basketball, volleyball, soccer) [11]. In contrast research has also shown no lower limb dominance changes in BMC, LM and muscle torque in collegiate soccer players [10] or maximal leg power in non-athletes [22] Research highlights mixed associations for individual limb dominance of the upper extremities when considering limb musculoskeletal composition, strength and level of competition, and fewer within-subject designed studies targeting limb dominance bone adaptations for the lower extremities [12,23,24]. Despite these noted differences in other sports, variations for BMC, LM or muscle strength has not been investigated in combat athletes.

Regular participation in sports and physical conditioning has been shown to be beneficial for the development and maintenance of musculoskeletal function and performance [13,25]. Research has highlighted the importance of balanced loading in unilateral dominant and bilateral sports and activities [26-28]. Therefore, it is envisaged that performing a bilateral sport or activity should highlight less incidences of muscle imbalance regardless of limb dominance. The primary aim of this exploratory study was to quantify BMD and

LM in amateur male combat athletes. Further, this research aimed to explore the associations of limb dominance characteristics with muscular strength and striking power.

Methods

Experimental approach to the problem

A cross-sectional exploratory study was conducted to examine musculoskeletal limb symmetry in amateur male combat athletes. To assess limb symmetry all participants were assessed for BMD and LM for the dominant and non-dominant limbs. Limb dominance was considered the independent variable while BMD, LM, adiposity (percent body fat), strength and striking power were considered the dependent variables.

Participants

A convenience sample of thirteen healthy, experienced, recreational male amateur combat athletes from the local community volunteered for this study and completed all physiological tests. Lightweight combat participants (n=5) were defined as combat athletes competing at a body mass <70.3 kg and middleweight combat athletes (n=8) competing at a mass <83.9 kg [13].

A random sample of 15 sedentary (not meeting physical activity guidelines of ≥ 150 mins/week and describing themselves as inactive) individuals (from a database of approximately 5,000), matched by gender, mass and body mass index was used for comparison of selected Dual-Energy X-ray Absorptiometry (DXA) outcome variables. Participant characteristics, bone density, lean muscle mass, body composition, strength and striking power are reported in Table 1. Combat participants were accepted into the study upon completion of a health and injury screening using stage one of the Exercise and Sport Science Australia Adult Pre-Exercise Screening System [29], participants were currently training and had a minimum of two years Mixed Martial Arts (MMA) or kickboxing training. All participants provided written informed consent prior to data collection and the study was approved by Central Queensland University Human Research Ethics committee (H16/03-056).

Table 1: Participants' demographics. Values are mean ± standard deviation or number (n). Where: * denotes p<0.05 (lightweight vs. Middleweight); # denotes p<0.05 (combat group vs. controls).

Characteristics	Group (n=13)	Light weight (n=5)	Middle weight (n=8)	Controls (n=15)
Age (yrs)	28.8 ± 4.57	27.2 ± 4.7	29.7 ± 4.4	41.2 ± 8.89 #
Mass (kg)	80.9 ± 12.24	70.6 ± 2.8	87.5 ± 11.3*	80.06 ± 7.8
Height (cm)	176.9 ± 4.14	174.0 ± 2.9	178.6 ± 3.8*	181.0 ± 5.3
BMI (kg/m^2)	25.9 ± 3.8	23.3 ± 0.9	27.5 ± 4.1*	24.5 ± 2.7
• normal (18.5- ≤24.9 kg/m^2) (n)	7	5	2	9
• Overweight (≥ 25.0- ≤29.9 kg/m^2) (n)	4	0	4	6
• Obese (≥ 30.0 kg/m^2) (n)	2	0	2	0
Total body fat (%)	13.3 ± 4.4	11.7 ± 4.3	14.3 ± 4.3	18.2 ± 2.4 #
VAT mass (grams)	296.8 ± 120.5	235.8 ± 43.7	334.8 ± 139.6	503.7 ± 161.2#
Est VAT area (cm^2)	61.6 ± 24.9	49.2 ± 9.1	69.5 ± 28.9	104.4 ± 33.5 #
Bone mineral density				
Total body BMD (g/cm^2)	1.29 ± 0.10	1.25 ± 0.9	1.31 ± 0.9	1.19 ± 0.10 #
Lumbar spine BMD (g/cm^2)	1.24 ± 0.12	1.20 ± 0.2	1.26 ± 0.1*	1.09 ± 0.20 #
Dominant arm BMD (g/cm^2)	0.92 ± 0.06	0.90 ± 0.03	0.94 ± 0.08*	0.89 ± 0.07
Non-dominant arm BMD (g/cm^2)	0.90 ± 0.09	0.89 ± 0.05	0.93 ± 0.09*	0.88 ± 0.07
Dominant leg BMD (g/cm^2)	1.37 ± 0.11	1.32 ± 0.06	1.40 ± 0.12	1.34 ± 0.12
Non-dominant leg BMD (g/cm^2)	1.32 ± 0.11	1.27 ± 0.05	1.36 ± 0.11	1.31 ± 0.11
Lean Mass				
Dominant Arm lean mass (g)	4643.4 ± 803	4103.9 ± 280	4980.7 ± 850*	4219.2 ± 1093
Non-dominant arm lean mass (g)	4372.1 ± 1092	3937.3 ± 219	4643.8 ± 873	3929.6 ± 1004
Arms: Dominant to non-dominant lean mass difference (g)	271.4 ± 179	166.7 ± 80	336.9 ± 196*	289.7 ± 151
Dominant Leg lean mass (g)	11712.8 ± 1787	10325.0 ± 684	12580.3 ± 1723*	12325.5 ± 2181
Non-dominant leg lean mass (g)	11284.3 ± 1747	9906.3 ± 645	12145.5 ± 1671*	11798.1 ± 2034
Legs: Dominant to non-dominant lean mass difference (g)	428.8 ± 338	418.7 ± 394	435.2 ± 327	527.5 ± 323
Strength				
5RM bench press (kg)	82.35 ± 19.78	67.4 ± 14.0	87.1 ± 17.54*	- -
5RM bench press (5rm/kg)	0.98 ± 0.15	0.95 ± 0.19	0.99 ± 0.11	- -
5RM back squat (kg)	104.92 ± 34.00	83.4 ± 17.7	116.2 ± 43.1	- -
5rm back squat (5RM/kg)	1.30 ± 0.30	1.18 ± 0.26	1.31 ± 0.35	- -
Power				
Jab punch (W)	7817 ± 3117	7396 ± 2068	8081± 3742	- -
Jab punch (W/kg)	97.3 ± 34.6	105.7 ± 33.2	92.1± 36.7	- -
Cross punch (W)	15353 ± 4565	15,228 ± 5497	15,431 ± 4294	- -
Cross punch (W/kg)	193.8 ± 66.1	218.5 ± 87.2	178.4± 49.5	- -
Front kick (W)	8144.6 ± 2573.2	8,563 ± 3095	7,882 ± 2381	- -
Front kick (W/kg)	102.0 ± 34.9	120.7 ± 41.1	90.3± 26.8	- -
Round house kick (W)	44607 ± 12268.00	46,377 ± 12209	43,500 ± 13,008	- -
Round house kick (W/kg)	565.0 ± 194	663.1 ± 198	503 ± 177	- -

Procedures

A cross-sectional design was used to compare the BMD and segmental lean mass adaptations of trained, recreational amateur combat athletes striking impact power (punch and kicks) and strength (5RM) performance. Sedentary controls were used as comparison for selected DXA outcome variables. Initial testing involved collection and recording of participant demographic details and measuring body mass in light clothing without footwear to the nearest 0.1 kg using calibrated scales (Seca GMBH, Hamburg) and height to the nearest 0.1 cm with a stadiometer (Seca GMBH, Hamburg). Body Mass Index (BMI) was calculated from mass and height (BMI kg/m2=mass/ height2). All DXA measurements were performed following an overnight fast with participants avoiding strenuous exercise the 24 hours prior to testing and attended in a euhydrated state. Participants were assessed using a full body DXA scan to assess whole body BMD and segmental body composition (including Visceral Adipose Tissue (VAT)). A total body scan was selected as this has been shown to provide the identification of osteoporosis at numerous skeletal sites and data on body composition. DXA is recognized as the gold standard for assessment of body BMD and body composition in a single scan, thereby reducing exposure to radiation [30,31]. All participants were scanned according to Australian Institute of Sport best practice protocols for a total body scan [32].

Dual energy x-ray absorptiometry

Dual energy x-ray absorptiometry (Hologic Discovery W using Apex 4.5.2 analysis software) was used to measure the BMD (g/cm2) of the total body. All scanning procedures were standardized for all participants following the guidelines of the DEXA manufacturer and the standards outlined by International Society for Clinical Densitometry (ISCD). Quality assurance procedures were performed daily adhering to manufacturers' recommendations and current clinical guidelines. The acquisition and the analysis of all bone scans were performed by the same Certified Clinical Densitometrist. Prior to conducting the study, a pilot study was conducted to determine the reliability of data collection and analyses. The bone density research laboratory Coefficients of Variation (CV) for precision and accuracy for the spine phantom were 0.3% and 0.4%, respectively. In vivo precision CV for the CCD are 0.9% for total body, 0.6% for AP spine (L1-L4), 0.2% for left total hip, 0.2% for right total hip, 0.1% for right and left wrist BMD sites.

(-13.8%, $p \leq 0.05$) lumbar spine BMD than combat groups combined. There was a large effect size (1.0) found between combat groups combined and controls with total body BMD and a medium effect size in lumbar spine BMD (0.66).

Middleweights were found to have a significantly higher (+4.4%, $p<0.05$) BMD in their dominant arm as compared to lightweights. Combat athletes had a non-significant higher dominant BMD (+3.3%) than controls. With regard to the non-dominant arm BMD, middleweights had a significantly higher (+3.3%, $p<0.05$) BMD however there was no difference between combat groups combined and controls.

With regard to BMD of the legs, there were no significant differences between combat groups or combat groups and controls. Middleweights have a non-significantly higher leg BMD in the dominant (+6.1%) and non-dominant legs (+7.1%) as compared to lightweights. With regard to controls, as a group combat athlete had a non-significantly higher leg BMD in the dominant (+2.2%) and a slightly lower BMD in the non-dominant leg (+0.1%).

With regard to symmetry of BMD, there were no significant differences between combat groups or combat versus controls. With regard to dominant versus non-dominant arm BMD, combat participants had a non-significant +2.31% higher BMD in their dominant arm while controls had a +0.01% higher BMD difference. There were also no significant differences in dominant and non-dominant leg BMD between combat groups (+3.8%) and combat groups and versus controls (+2.2%).

Lean and fat mass

With regard to lean mass, there were significant differences ($p<0.05$) between combat groups with regard to dominant arm (+23.4%) and dominant leg (+21.8%). There was no difference between non-dominant arm and non-dominant leg however; middleweights had a higher lean mass in both (+17.9% and +22.6%, respectively). With regard to symmetry, there was no significant difference between combat groups (arms: lightweights 166 grams versus middleweights 336 grams; legs, lightweight 418 versus middleweight 435 grams). There was also a non-significant difference with regard to lean mass symmetry between combat groups combined and controls (arms combat 271 grams, controls 289 grams) or legs (combat 428 grams, controls 527 grams).

There was a significant difference ($p<0.05$) between combat groups with lightweights having less lean (absolute) mass in their dominant arm (-21.4%). There was also a significant difference ($p<0.05$) with regard to absolute lean mass in the dominant arm to non-dominant (-102%). There was no difference between combat groups with regard to absolute lean mass in their non-dominant arms.

With regard to dominant and non-dominant leg lean mass, middleweights had a significantly ($p<0.05$) higher lean absolute lean mass (+21.8%) in the dominant leg and non-dominant leg (+22.6%). There was no difference between dominant and non-dominant leg with regard to lean mass difference (welterweights 435 grams vs. lightweights 418 grams).

With regard to symmetry of lean mass, there were no significant differences between combat groups, they ranged from 5.89% to 3.65% in lean mass between dominant and non-dominant arms and legs while sedentary controls ranged from 4.47% to 8.86% between dominant and non-dominant arms.

With regard to strength tests, only completed in the combat athletes, middleweights had a significantly higher 5RM bench press (+22.2%, $p<0.05$) however when normalized to mass, there was a non-significant difference between combat groups (+4.2%). Despite a heavier 5RM squat (+39.3%) in the middleweight group, the difference was non-significant ($p=0.138$) between groups.

With regard to punching and kicking power, there were no significant differences identified with the jab punch or cross punch between groups, middleweights demonstrated higher, non-significant absolute power outputs across both punches (1.3% to 9.3%). However, lightweight combat athletes had a non-significant, higher absolute power output in the front kick (+8.6%, $p=0.663$) and roundhouse kick (+6.2%, $p=0.669$). With regard to relative power output, lightweight combat athletes demonstrated a non-significant higher relative power output in all punches (+14.8% to +22.4%) and kicks (+31.8% to +33.5%).

With regard to correlations, there were a number of significant correlations between 5RM strength (absolute and relative) and outcome variables of BMD and lean mass (Table 2). Bench press and half-squat 5RM was significantly related to both dominant, non-dominant BMD in the arm and leg, as well as total body BMD and lead hand jab punch power. Regarding effect size, arms and leg (dominant and non-dominant) BMD effect sizes and legs lean mass (dominant and non-dominant) were all small ranging from 0.25 to 0.17.

Table 2: Correlations and significance (correlation/p-value) between strength, BMD and power in combat athletes. (n =13, where * indicates $p<0.05$, ** indicated $p<0.001$)

Variable	5RM Bench press	5RM leg press	5RM Leg press/mass
Dominant arm BMD (g/cm^2)	.703/0.007*	.805/0.001**	.660/.014*
Non-dominant arm BMD (g/cm^2)	.776/0.002*	.807/0.001**	.588/.035*
Dominant leg BMD (g/cm^2)	.665/0.013**	.808/0.001**	.658/.014*
Non-dominant leg BMD (g/cm^2)	.669/0.012**	.839/0.000**	.704/.007*
Total body BMD (g/cm^2)	.586/0.035*	.627/0.022*	.456/.117
Lead hand jab punch (watts)	.565/0.044*	.671/0.012**	.686/.01*
Rear hand punch (watts)	.216/.479	.250/.410	.359/.228
Rear leg kick (watts)	-0.16/.958	.251/.409	.275/.364
Rear leg roundhouse (watts)	-.232/.445	-.109/.724	-.113/.713

Discussion

The primary aim of this cross-sectional exploratory study was to examine musculoskeletal limb symmetry in amateur male combat athletes and their association with muscle strength, BMD and striking power. Firstly, the outcomes of this study revealed that the upper limbs of combat athletes displayed symmetry for BMD and lean muscle, however favourably for the dominant limb. The results observed for the stronger asymmetrical musculoskeletal balance issues in the upper limb of amateur combat athletes should represent a concern for further imbalance and injury. Finally, the association of the upper limbs musculoskeletal composition appears more coupled with strength and striking power than the lower limbs. These results suggest that lean muscle mass has a complex role in the relationship with BMD health of combat athletes.

The amateur combat athletes assessed in the present study appear to favour their dominant upper limb resulting in significant differences in BMD and lean muscle. Although the changes represent asymmetry between the dominant and non-dominant limbs the impact of BMD