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Title:

Vertical jump on a force plate for assessing muscle strength and power in women with severe obesity: reliability, validity and relations with body composition

Running head:

Muscle strength and power in subjects with obesity

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ABSTRACT

Muscle strength and power, particularly when assessed during multi-joint movements such as vertical jump (VJ), are important predictors of health status and physical function. VJ is mainly used in athletes, but also in untrained or older adults, but has not yet been used in subjects with obesity. We aimed to assess in this population: 1) the reliability of VJ parameters, 2) their validity compared to isokinetic testing, 3) their relations with body composition. In 20 women with severe obesity (mean [SD] age: 41.1 [11.6] years, BMI: 43.9 [4.4] $kg.m^{-2}$) without severe orthopedic disorders, VJ parameters, knee extension torque and body composition were assessed using a force plate, an isokinetic dynamometer and dual x ray absorptiometry, respectively. Excellent reliability was found for absolute peak power and peak force in VJ (ICC [95% CI]: 0.95 [0.88-0.98] and 0.90 [0.77-0.96], respectively), and moderate to good validity of peak power and peak force compared to isokinetic torque (0.79 and r=0.67, respectively, all P<0.01). Positive relations were found between peak force and peak power during VJ and lean body mass (r=0.89 and r=0.60, respectively, P<0.01) and a negative relation was found between peak velocity or VJ height and fat mass (r=-0.65 and -0.64, respectively, P<0.01). These results suggest that VJ on a force plate is a reliable and valid test for assessing muscle strength and power in severely obese subjects. VJ testing is easy to implement, which can facilitate its use in both research and clinical testing in this setting. (ClinicalTrials.govID: NCT03325764).

Keywords: muscular fitness, vertical jump, force plate, isokinetic testing, obesity

Word count: 3370

INTRODUCTION

The worldwide prevalence of obesity (defined as body mass index, BMI, ≥ 30 $kg.m^{-2}$) and severe obesity (i.e. BMI ≥ 40 $kg.m^{-2}$) has markedly increased over the last decades and reached up to 39% and 7.6% of the US adult population in 2016, respectively (18). Obesity is associated with an increased risk of type 2 diabetes, cardiovascular disease, certain forms of cancer, and premature mortality (20), but also with lower muscular fitness and physical function (10). In aging subjects with obesity, low muscle mass, strength and function lead to so-called "sarcopenic obesity", which is associated with deleterious health effects (31). Growing evidence suggests that such deterioration of muscle properties can occur earlier in life (31). As recently reviewed, middle-aged subjects with obesity have lower muscle strength and power when normalized to body mass, lean body mass or muscle cross sectional area (10). Low relative strength and power may be an important factor explaining the lower physical function usually described in this population (12, 14, 26).

Lean body mass and knee extension strength have been identified as predictors of walking capacity in subjects with obesity (12, 14, 26). Muscle power assessed during 5 consecutive jumps was also found to be associated with physical performance (i.e. stair climbing and running speed) in this population (28). Muscle power has long been recognized as a critical determinant of athletic performance (27), and growing evidence also suggests the importance of muscle power for carrying out daily living activities in aging individuals (11). Power-training, also called high-velocity resistance training, has recently emerged as potentially more effective than traditional strength training for improving physical function in older adults, including those with sarcopenic obesity (6). To further document the relations of muscle strength and power with physical function in subjects with obesity, there is a need to

identify methods that can be performed in this population with sufficient precision and safety, and that would be feasible in routine clinical care.

In clinical settings, handgrip strength is the most widely used measure of muscle strength. Although predictive of health status (13), handgrip strength cannot be used as a surrogate of lower-limb strength (9). Inversely, isokinetic testing, recognized as the gold-standard method for assessing lower-limb strength (1), is not easily accessible in all settings, is time-consuming and requires trained personnel, limiting its use in a clinical context. Vertical jump is another test frequently used for the assessment of lower-limb strength and power (40) but so far, its use has mainly been limited to athletes. However, several studies have shown good reliability and validity of vertical jump parameters in other populations such as untrained (36) and older adults (15, 21). A previous study by Lafortuna et al. (28) had also shown the feasibility of performing 5 consecutive jumps in adults with severe obesity, despite a higher prevalence of orthopedic disorders (i.e. joint pain, osteoarthritis) in this population (2). Vertical jump might therefore be adapted to adults with obesity but its reliability and validity have not been assessed.

Therefore, the aims of this study were to investigate in subjects with severe obesity: 1) the intra-session reliability of vertical jump parameters assessed with a force plate, 2) the validity of this method compared to the gold-standard assessment of knee extension strength with an isokinetic ergometer, 3) the relations of vertical jump parameters and knee extension strength with body composition.

METHODS

Experimental approach to the problem

A cross-sectional study was conducted in subjects with severe obesity. The description of participants included age, anthropometrics, body composition assessed by dual x ray absorptiometry (DXA, Hologic Discovery W, software v12.9; Hologic, Bedford, MA), physical function assessed with a 6-min walk test and habitual physical activity assessed by accelerometers (Actigraph GT3x accelerometer, Manufacturing Technology, Inc., FL, USA). To answer the first study aim, the intraclass correlation coefficients (ICC) and r^2 from r correlation coefficients were calculated for six vertical jump parameters (absolute peak force and power, relative peak force and power, peak velocity and jump height) assessed on a force plate (Kistler, Winterthur, Switzerland; type 9286BA, dimensions 60 x 40 cm). To answer the second study aim, correlation coefficients between vertical jump parameters and knee extension strength assessed with an isokinetic ergometer (Con-Trex, CMV AG, Dübendorf, Switzerland) were analyzed. Finally, to answer the third study aim, the relations of vertical jump parameters and knee extension strength with body mass, body fat and lean body mass by were analyzed.

Subjects

Participants for this study were recruited among patients with severe obesity followed at a single academic center and who were candidates to bariatric surgery (sleeve gastrectomy). Recruitment took place between October 2017 and July 2018. Inclusion criteria were female gender, age between 18 and 65 years, place of residence in Paris or its region, BMI of 40 $kg.m^{-2}$ or higher or BMI of 35 $kg.m^{-2}$ or higher with at least one obesity comorbidity. Following national (19) and international (33) guidelines for the management of patients seeking this type of surgery, exclusion criteria were: abnormal cardiac stress test, recent coronary event, orthopedic disorders or neuropathy that would limit physical activity, on-

going or planned pregnancy. All patients were informed about the benefits and risks of the investigation and signed an informed written consent to join the study. The study was approved by the Ethics Committee of Bron Hospital (Comite de Protection des Personnes Sud-Est III, Bron, France) (clinicaltrials.gov NCT03325764).

Twenty subjects aged from 21 to 63 years were included in the study. Parameters related to age, anthropometrics and body composition-are shown in Table 1.

Physical function and objective physical activity data are presented in Table 2. The mean (SD) 6-min walk test distance was 513 (41) m. Participants wore the accelerometers over a mean (SD) of 6.8 (0.5) days-and 15 (75%) participants reached the recommended PA level.

Procedures

Body composition (DXA), vertical jump parameters, knee extension strength and physical function were assessed during two consecutive visits within 4 weeks. The second visit took place at our laboratory equipped with a force plate and an isokinetic ergometer. Habitual PA was assessed during 7 days between the two visits.

Description of participants

BMI was calculated as body mass (kg) divided by height squared (m^2). Body composition (fat mass, lean body mass) was measured by DXA scanning, as previously described (35). Physical function was assessed with a 6-min walk-test performed in an indoor 30-m corridor according to the recommendations of the American Thoracic Society (3). Participants were asked to walk for 6 min between two cones, covering as much distance as possible. Heart rate

(HR) was recorded throughout the test with a Polar M200 Sports optical HR sensor (Polar Electro Oy, Kempele, Finland) (23).

Participants were asked to wear the Actigraph accelerometer at the hip for seven consecutive days during all waking hours except during water-based activities. Data were considered valid when the accelerometer was worn for at least 4 days during at least 8 h each day (35). Based on previous literature, cut-points below 100 counts.min^{-1}, between 100 and 1,951 counts.min^{-1}, between 1,952 and 5,723 counts.min^{-1} and over 5,724 counts.min^{-1} were used to quantify sedentary behaviour, light, moderate and vigorous intensity PA, respectively (17). Patients were considered compliant to the 2018 US PA guidelines when total MVPA was ≥ 150 min.week^{-1} (37).

Vertical jump

Vertical jump ability was assessed using counter-movement jump (CMJ) performed on a force plate. Participants performed several practice trials of sub-maximal CMJ under the supervision of the research staff to ensure correct execution. After the practice jumps, participants completed two maximal CMJ, with at least 3 min rest between trials. At the beginning of each trial, participants were asked to stand still on the force plate to register body weight. From the initial standing position (with feet shoulder-width apart and hands on hips), participants were asked to initiate a downward movement immediately followed by an upward movement leading to take-off, and to maintain a standing position during at least 3 s (40). Participants self-selected a degree of knee flexion that they felt comfortable with (15). Vertical ground reaction force (F_z) was recorded at a sampling frequency of 1000 Hz. Peak force (in N), peak velocity (in cm.s^{-1}) and peak power (in W) in the vertical axis, defined as the maximum values obtained between the start of the jump and take-off, were obtained using

the Kistler software. Peak power and peak force were also expressed relative to body mass (in $W.kg^{-1}$ and $N.kg^{-1}$, respectively).

F_z component was used to calculate the vertical instantaneous acceleration of the centre of mass (a_z, expressed in $m.s^{-2}$) as follows:

$$a_z = \frac{F_z}{m} - g \qquad (1)$$

where m is the body mass (in kg) and g the acceleration due to gravity. a_z was then integrated once to provide instantaneous vertical velocity (v_z, expressed in $m.s^{-1}$).

$$v_z = \int a \ dt + v_{z0} \qquad (2)$$

As the jump begins with a period of immobility, at t_0, $v_{z0} = 0$.

Power output was then calculated as the product of force and velocity ($P_z = F_z . v_z$, in W).

Time in the air (identified as the period between take-off and contact after flight), was used to calculate height jump, as follows:

$$height = \frac{1}{8} \ g \ (TIA)^2 \qquad (3)$$

where TIA is the time in the air (cm).

Knee extension strength

Isometric and isokinetic concentric quadriceps muscle strength was assessed using a Con-Trex isokinetic ergometer. Only the right lower limb was tested. Positioning of the subjects was standardized, with subjects seated on the ergometer so that the hip was flexed at 85° (0°: full hip extension). Participants performed several practice trials of sub-maximal isometric and isokinetic contractions. Isometric concentric torque was assessed with the knee angle set at 70° (0°: full leg extension). Two trials were performed with 90-s rest between trials. Isokinetic concentric torque was assessed at angular velocities of 60 and $240°.s^{-1}$. The range of motion was fixed from 10° to 90°. One trial was performed at each angular velocity.

During the isometric and isokinetic tests, participants were strongly encouraged to produce their maximal force during 3 s and throughout the range of motion, respectively.

Statistical analyses

Descriptive data are presented as mean (SD) and min-max values to characterize inter-individual variability. Intraclass correlation coefficients (ICC) with 95% confidence intervals and r^2 from Pearson correlation coefficients were used to assess intra-session reliability of vertical jump parameters. Pearson correlations were also used to assess the validity of vertical jump parameters against isokinetic and isometric knee extension torques, and to analyze the relations of vertical jump parameters and knee extension torques with body composition parameters. P-values < 0.05 were considered significant. ICC values and correlation coefficients less than 0.5, between 0.5 and 0.74, between 0.75 and 0.89 and ≥ 0.90 were considered indicative of poor, moderate, good and excellent reliability or validity, respectively (34). Analyses were performed using R version 3.4.3 (R Core Team: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. 2017).

RESULTS

Vertical jump parameters and knee extension torque are presented in Table 3. Mean (SD) peak power, peak force and jump height were 2604 (560) W, 2034 (289) N and 8.8 (2.9) cm, respectively. Mean isometric torque was 167.4 (34.9) Nm.

Intra-session reliability of vertical jump parameters

Reliability parameters (coefficient correlation r^2, ICC) are presented in Table 4 for six CMJ variables (absolute and relative peak power and peak force, peak velocity and jump height). Findings revealed excellent reliability for absolute and relative peak power and for absolute peak force, as documented by ICC $\geq$ 0.90 and r^2 correlation coefficients > 0.80. Reliability was good for peak velocity and jump height and moderate for relative peak force. The variable with the highest index of reliability was absolute peak power (ICC [95% CI] = 0.95 [0.88-0.98] and r^2=0.90, P<0.001).

Validity of vertical jump parameters compared to knee extension strength

Relations of peak power, peak force and jump height with isometric and isokinetic knee extension torque are presented in Figure 1. Peak power in vertical jump was positively correlated to all measures of isokinetic and isometric torque (Figure 1 a-c). Peak force in vertical jump was significantly correlated to isokinetic torque (Figure 1 d-e) but was not significantly correlated to isometric torque (Figure 1f). Jump height was significantly correlated to isokinetic torque at $60°.s^{-1}$ and isometric torque (Figure 1 h-i) but was not significantly correlated to isokinetic torque at $240°.s^{-1}$ (Figure 1g). The highest correlations were obtained between peak power and isokinetic torque at $60°.s^{-1}$ (r=0.79, P<0.001) and between jump height and isokinetic torque at $60°.s^{-1}$ (r=0.72, P<0.001).

Relations between vertical jump parameters and body composition

As shown in Table 5, age and height were significantly correlated to most vertical jump parameters. Therefore, adjustment on age and height was performed when examining the relations of these parameters with body mass, lean body mass and body fat. Body mass was significantly correlated to peak force, negatively correlated to jump height and tended to be negatively correlated to peak velocity (P=0.06). No relation was observed between body mass

and peak power. Similarly, fat mass was positively correlated to peak force and negatively correlated to jump height and peak velocity, and was not significantly correlated to peak power. Lean body mass was positively correlated to peak power and peak force but was not significantly correlated to jump height and peak velocity. The strongest relation was between lean body mass and peak force ($r=0.89$, $P<0.001$).

Relations between knee extension strength and body composition

After adjustment on age and height (Table 3), isokinetic torque at $240°.s^{-1}$ was significantly correlated to lean body mass and tended to be correlated to body mass ($P=0.06$). No other significant relation was found between isometric or isokinetic torque at $60°.s^{-1}$ and body composition.

DISCUSSION

In this study, we measured lower-limb strength and power in women with severe obesity during vertical jump using a force plate and compared these data with lower-limb strength assessed on an isokinetic dynamometer. As expected, the mean absolute values of knee extension torque and peak force and power during vertical jump appeared higher than values described in adult lean women (15, 32), but were similar to values usually reported in women with severe excess body weight (24, 25). In contrast, jump height was more than twice lower than values described in adult lean women (15). There is, however, no other study to compare our data of vertical jump parameters in women with obesity or severe obesity.

The first aim of this study was to assess the intra-session reliability of vertical jump parameters on a force plate in women with severe obesity. Excellent reliability for peak

power and peak force during vertical jump were found. ICC values were ≥ 0.90 and similar to that previously reported in young to middle-aged healthy adults (15, 22). Lower, although good reliability was also found for jump height. These findings suggest that vertical jump, which is widely used to assess lower-limb strength and power in populations from athletes to older adults is also a reliable test in women with severe obesity in the age range 20 to 60 years. It should be acknowledged, however, that only women free of severe orthopedic disorders were included in our study. Given the higher prevalence of joint pain ~~(27)~~ or osteoarthritis (2) in subjects with obesity, careful medical check-up should be performed before proposing vertical jump testing.

The second aim of this study was to assess the validity of vertical jump parameters compared to the gold-standard assessment of knee extension torque with an isokinetic ergometer. Strong significant relations were found between peak power in vertical jump or jump height and isokinetic torque at $60°.s^{-1}$. The correlation coefficients observed here, between-0.72 and 0.79, were similar to that previously reported in athletes (r=0.77) (38), untrained adults (r=0.70) (36), or older adults (r=0.78) (21). A significant although lower relation was also found between peak power in vertical jump or jump height and isometric torque. Overall, these findings suggest moderate to good validity of vertical jump parameters compared to isokinetic strength, and poor validity compared to isometric strength in women with severe obesity. They also are in agreement with the notion, previously described in athletes that isometric contractions are very different from the actions involved in vertical jump and, consequently, that isometric strength is not a good predictor of vertical jump (4).

Another important aspect of this study was to analyze the relations of vertical jump parameters and knee extension torque with body composition. Peak force in vertical jump

was positively correlated to body mass, lean body mass and fat mass, and the strongest relation was with lean body mass (r=0.89). Peak power in vertical jump was positively correlated to lean body mass but peak velocity and height jump were negatively correlated to body fat. Therefore, as previously described in athletes (16), body composition appears to be a better predictor of vertical jump performance than body mass alone in subjects with obesity. Interestingly, only isokinetic torque at high angular velocity was significantly correlated to lean body mass. The correlation coefficient (r=0.49) was similar to that previously described in obese women (r=0.47) (25), although very few studies have analyzed relations between knee extension torque and body composition in this population. In our study, vertical jump parameters were more positively correlated to body composition than isokinetic or isometric torque, which suggests that multi-joint weight-bearing movements might better reflect body composition than isolated single-joint movements (21).

The relations observed here between vertical jump parameters and body composition strengthen the notion that absolute values of lower-limb strength increase with body mass. Several studies have reported higher absolute strength in obese vs. normal-weight subjects (10) without describing the relation between muscle strength and body mass in subjects with severe obesity. Given the major contribution of muscle strength in performing daily-living activities in subjects with obesity (5, 8, 30), higher muscle strength is likely to have beneficial effects regarding physical function. In contrast, our data showed that peak velocity in vertical jump and jump height decreased with body fat and that peak power was not significantly correlated to body mass. This is in line with previous studies that reported lower velocity and lower relative power during either 5 consecutive jumps or 5 sit-to-stand transitions in obese subjects (28, 39). In older adults, muscle power is recognized as a critical determinant of physical function (11). Moreover, power training has been proven to be more effective than

traditional resistance training to improve physical function (11). Although data on muscle power in subjects with obesity are scarce, there is some evidence that muscle power is an important contributor to stair climbing and sprinting performance in this population (28). More data from large-scale studies are needed to better understand how muscle power affects physical function and activities of daily living (e.g. walking velocity) in subjects with obesity.

Strengths and limitations

Strengths of this study include the use of gold-standard methods for the assessment of knee extension strength (isokinetic ergometer), lower-limb power (force plate) and body composition (DXA absorptiometry). Data were obtained in a homogeneous group of women with severe obesity candidates to the same bariatric surgery procedure. We were able to show good reliability and validity of vertical jump parameters, as well as significant relations of these parameters with body composition. Some limitations should be mentioned. We assessed only the intra-session reliability of vertical jump parameters, and did not assess the inter-session reliability. The sample size was relatively small and only women free of severe orthopedic disorders were included, which prevents us from extrapolating results to all obese subjects. It has been shown that relations between body composition and muscle power differed by sex in subjects with obesity (29). Validity of vertical jump parameters and relations with body composition should also be explored in men with obesity.

Conclusion

This study showed excellent intra-session reliability of vertical jump parameters in women with severe obesity and moderate to good validity compared to isokinetic testing. Interestingly, vertical jump parameters were more positively correlated to body composition than isokinetic or isometric strength. This emphasizes the importance of measures of muscle

strength during multi-joint~~s~~ movements, known to better predict physical function compared to muscle strength assessed during single-joint movements. Peak force in vertical jump was strongly and positively correlated to lean body mass, whereas jump height and peak velocity were negatively correlated to fat mass. Peak power, a critical determinant of physical function, was not correlated to body mass, suggesting a potential deficit in muscle power with increasing BMI.

PRACTICAL APPLICATIONS

Vertical jump testing is easy and rapid to implement, whereas isokinetic testing is more challenging, especially because of time constraints (about half an hour vs. a few minutes for vertical jump) and difficulties for positioning subjects with severe obesity on the ergometer. Vertical jump might therefore be used more broadly in both clinical and research setting with the aim to better describe muscular fitness in adults with and to assess the effect of an intervention. Although the reliability of jump height and its validity compared to isokinetic testing were lower than that of peak power, good and moderate reliability and validity were found, respectively. Contrary to peak power, jump height has the advantage of being easily understandable by patients. In addition, jump height can be assessed accurately with less expensive methods than the force plate such as smartphone applications (7), which might facilitate its measure in routine. It is important to note that obesity is often associated with joint pain. We therefore recommend to carefully examine the medical record and to obtain medical authorization before proposing vertical jump testing to these subjects. To generalize vertical jump testing in this population, there is a need to confirm the feasibility of vertical jump in a larger sample of subjects and to establish normative values of vertical jump parameters in this population.

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Figure title

Figure 1- Relations between vertical jump parameters and knee extension torque (N=18)

Figure legend

Figure 1- Pearson correlations (unadjusted) between peak power in CMJ and peak isokinetic torque at 240°.s^{-1} (a), peak isokinetic torque at 60°.s^{-1} (b), peak isometric torque (c), ~~and~~ between peak force in CMJ and peak isokinetic torque at 240°.s^{-1} (d), peak isokinetic torque at 60°.s^{-1} (e), peak isometric torque (f) and between jump height and peak isokinetic torque at 240°.s^{-1} (g), peak isokinetic torque at 60°.s^{-1} (h), peak isometric torque (i)

Table 1- Participants characteristics (N=20)

	Mean (SD)
Age, years	41.1 (11.6)
ANTHROPOMETRICS AND BODY COMPOSITION	
Height, cm	162.4 (5.7)
Body mass, kg	116.1 (16.1)
BMI, $kg.m^{-2}$	43.9 (4.4)
Body fat, %	49.4 (3.3)
Lean body mass, kg	55.5 (6.9)

Abbreviations: BMI, body mass index

Table 2- Physical function and accelerometry-assessed physical activity data (N=20)

	Mean (SD)
6-MIN WALK TEST	
Distance, m	513 (41)
Peak HR, bpm	140 (17)
PHYSICAL ACTIVITY	
Accelerometer wear time	14.8 (2.0)
Daily steps, steps.day^{-1}	6,864 (2,722)
Sedentary time, % wear time	64.2 (9.2)
Light-intensity PA, % wear time	31.8 (7.7)
Moderate-intensity PA, % wear time	4.0 (2.2)
Vigorous-intensity PA, % wear time	0.0 (0.0)

Abbreviations: HR, heart rate; PA, physical activity

Table 3- Vertical jump parameters and knee extension torque (N=20)

	Mean (SD)
VERTICAL JUMP	
Peak power	
Absolute, W	2604 (560.1)
Relative, $W.kg^{-1}$	22.2 (3.5)
Peak force	
Absolute, N	2034 (288.7)
Relative, $N.kg^{-1}$	17.3 (1.1)
Peak velocity, $m.s^{-1}$	1.55 (0.18)
Jump height, cm	8.8 (2.9)
KNEE EXTENSION STRENGTH (N=18)*	
Peak isometric torque	
Absolute, Nm	167.4 (34.9)
Relative, $Nm.kg^{-1}$	1.41 (0.32)
Peak isokinetic torque at $60°.s^{-1}$	
Absolute, Nm	133.6 (29.2)
Relative, $Nm.kg^{-1}$	1.12 (0.23)
Peak isokinetic torque at $240°.s^{-1}$	
Absolute, Nm	88.9 (18.3)
Relative, $Nm.kg^{-1}$	0.74 (0.12)

* Because of technical issues with the isokinetic ergometer encountered during the study, isokinetic data were obtained in 18 participants.

Table 4- Intra-session reliability of vertical jump parameters in women with severe obesity (N=20)

	Mean (SD)		Intra-session reliability	
	Test 1	**Test 2**	**r^2 (P-value)**	**ICC (95% CI)**
Peak power, W	2,412.0 (540.5)	2,597.0 (562.4)	0.90 (P<0.001)	0.95 (0.88-0.98)
Relative peak power, $W.kg^{-1}$	20.5 (3.4)	22.1 (3.5)	0.83 (P<0.001)	0.91 (0.79-0.97)
Peak force, N	2,020.0 (291.3)	2,039.0 (286.2)	0.81 (P<0.001)	0.90 (0.77-0.96)
Relative peak force, $N.kg^{-1}$	17.2 (1.6)	17.4 (1.1)	0.49 (P<0.001)	0.65 (0.31-0.85)
Peak velocity, $m.s^{-1}$	1.46 (0.17)	1.55 (0.18)	0.72 (P<0.001)	0.85 (0.65-0.94)
Jump height, cm	7.2 (2.6)	8.5 (2.9)	0.58 (P<0.001)	0.75 (0.48-0.90)

r are Pearson correlation coefficients (unadjusted); ICC (95% CI): intraclass correlation coefficient (95% confidence interval)

Table 5- Pearson coefficient correlations between vertical jump parameters, knee extension torque and body composition (N=20)

	Age[1]	**Height[1]** (cm)	**Body mass[2]** (kg)	**Lean body mass[2]** (kg)	**Fat mass[2]** (kg)
VERTICAL JUMP					
Peak power, W	**-0.58****	**0.64****	0.21	**0.60****	-0.05
Peak force, N	**-0.47***	**0.67*****	**0.78*****	**0.89*****	**0.54***
Peak velocity, $cm.s^{-1}$	-0.35	0.17	-0.46	0.06	**-0.65****
Jump height, cm	-0.21	0.19	**-0.54***	-0.11	**-0.64****
KNEE EXTENSION STRENGTH					
Peak isometric torque, Nm	**-0.62****	0.26	-0.20	-0.09	-0.19
Peak isokinetic torque at $60°.s^{-1}$, Nm	**-0.69*****	**0.54***	-0.10	0.10	-0.16
Peak isokinetic torque at $240°.s^{-1}$, Nm	**-0.51***	**0.53***	0.48	**0.53***	0.29

1- Unadjusted, 2- Adjusted on age and height

* P<0.05 ** P<0.01 *** P<0.001

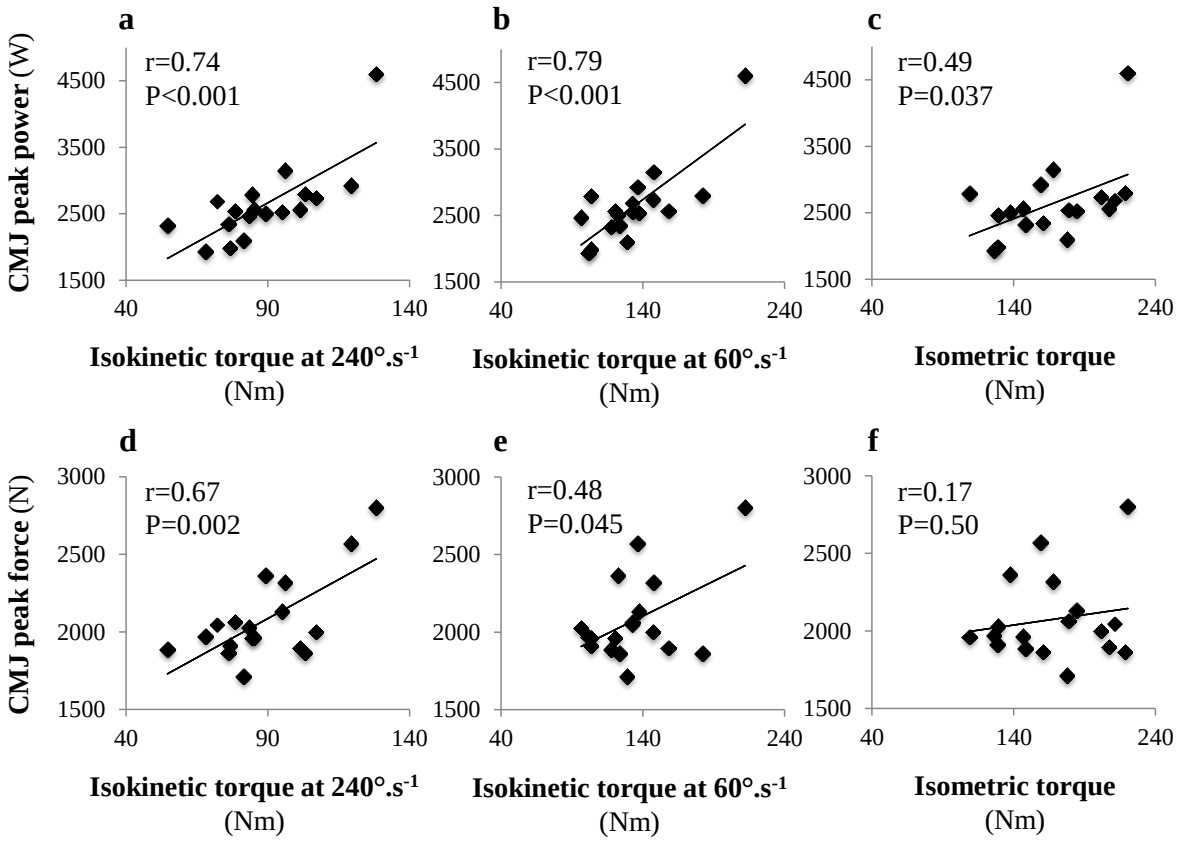
a
b
c
d
e
f
CMJ peak power (W)
CMJ peak force (N)
r=0.74
P<0.001
r=0.79
P<0.001
r=0.49
P=0.037
r=0.67
P=0.002
r=0.48
P=0.045
r=0.17
P=0.50
4500
3500
2500
1500
3000
2000
40
90
140
240
Isokinetic torque at 240°.s-1
(Nm)
Isokinetic torque at 60°.s-1
(Nm)
Isometric torque
(Nm)

Figure 1