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The Relationship Between Isometric Strength and Body Mass to Dynamic Performance in Youth Athletes

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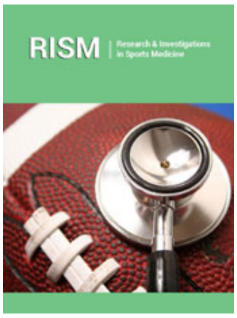

Lutton Greg* and Garrett Giles

School of Kinesiology, George Mason University, Manassas, VA 20109, USA

Abstract

The Relationship between Isometric Strength and Body Mass to Dynamic Performance in Youth Athletes. Nineteen youth athletes were assessed to evaluate correlations between isometric strength, total body weight and dynamic sports performance assessments. Athletes total body mass, lean body mass and percentage body fat were measured. Athletes performed isometric and dynamic performance assessments which were investigated for correlations to total body mass, lean body mass and percent body fat. Relative strength ratios were developed and compared to each of the dynamic performance assessments. Relative Strength Ratios (RSR) were found to correlate to dynamic sports assessments. The primary finding of this investigation suggests that relative strength ratios affect performance as athletes with RSR_{med} (1.5-2.0) to RSR_{high} (2.0+) performed better at dynamic assessments than those with RSR_{low} (<1.5). The secondary finding of this investigation suggests that thresholds do exist for RSR when compared to dynamic sports assessments. Assessing athletes via relative strength ratios considering isometric force production and total body mass with respect to lean body mass and percent body fat may provide additional insight into training programming and body composition modifications to increase dynamic sports performance.

***Corresponding author:** Greg Lutton, School of Kinesiology, George Mason University, Manassas, VA 20109, USA

Orcid: https://orcid.org/0000-0001-7973-6800

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Introduction

In sport competition, athletes that lift the most, jump the highest or run the fastest, most often succeed. Developing athletes to be strong, powerful and fast is a key component of many strength and conditioning programs. Absolute strength is often measured and compared amongst individuals. In strength and conditioning programs, absolute strength is typically measured as how much an athlete can lift in one repetition most referred to as an One-Repetition Maximum (1RM.) [1]. The athlete that lifts the most, moves the most typically wins. However, when there is a tie as can be the case in Olympic lifting, athletes with lower body mass are deemed the winner because they are moving more weight with respect to their body weight [2]. An 86kg athlete lifting 100kg has a better body mass to strength ratio; 100kg/86kg=1.16 than a 90kg athlete lifting the same load 100kg/90kg=1.11. This is considered relative strength and is just as important as absolute strength [3,4]. Strength and conditioning professionals commonly focus training on creating strong, powerful athletes. A search of "NCAA back squat standards" yields many articles suggesting athletes squat 2.5 times their body weight [4,5]. This is considered an absolute strength metric based on a relative strength metric. According to the CDC, the average weight for ages 11 to 17 is approximately 35-70kg [6]. For a 15yo, 55kg athlete, that would be 137.5kg. Developing a squat of that magnitude could take years to master for elite athletes and may not be recommended for youth or developing athletes especially when considering the demands of their sport and their physiological development [7,8]. Furthermore, there is a point of diminishing returns where increasing absolute strength fails to produce increases in dynamic sports performance.

Another element of the strength and conditioning professional is to assess athletes' abilities in multiple areas such as strength, Rate of Force Development (RFD), jumping, sprinting and change of direction (COD) [9]. This can be done by hosting an assessment day where data is collected on each athlete and then used to make decisions about training, placement on teams and overall player development. To assess strength, the use of the Isometric Mid-Thigh Pull (IMTP) may be used in place of a traditional 1RM [10]. Research shows the IMTP to squat 1RM is 75% meaning if an athlete produced 100kg of force during IMTP, they could potentially squat 75kg [11]. The deadlift was also correlated to IMTP indicating 77% of IMTP to deadlift 1RM [12]. Research also suggests IMTP peak force ($IMTP_{peak}$) and Dynamic Mid-Thigh Pull in the same position as the IMTP is 30% of $IMTP_{peak}$ force and are strongly related [13]. These studies suggest IMTP could be used to assess maximal strength in place of a 1RM strength test [10-14]. Commonly the IMTP is assessed using force plate technology, however, recent advancements in technology allow for the use of a strain gauge to assess maximum strength in the IMTP [15-17]. Studies have also shown IMTP is a useful tool for assessing athletes based on the ability for anyone to be able to do the assessment with little to no prior knowledge or training [11,10]. To assess jump performance, strength and conditioning professionals use various types of jumps ranging from the Counter Movement Jump (CMJ), Squat Jump (SJ) and Drop Jump (DRJ), using different jumps assessments for the measurement of various physical qualities [9]. Assessing speed and change of direction, many practitioners use a 10m and 20m sprint as well as the 5-10-5 change of direction test commonly known as the pro agility shuttle, which is widely used in NFL-style combines [9,18]. Multiple independent studies exist comparing qualities of these dynamic assessments to isometric assessments [19,20]. A recent systematic review comparing isometric force-time characteristics to dynamic performance assessments such as jump, sprint and change of direction suggesting IMTP metrics can provide insight into dynamic performance [17].

Recent research shows increase in body mass correlates to increased performance whereas increases in body fat percentage showed negative correlations to performance [21,18]. This suggests there could be a relationship of body mass to strength and that differences in these ratios could affect performance. It is because of this difference in body mass to strength ratio, also known as relative strength, that research should be done investigating the relationship between body mass and the isometric mid-thigh pull when compared to athletic performance assessments. To better understand the nature of body mass, research should explore body composition with respect to percent body fat and lean body mass to see if a relationship exists when compared to dynamic performance assessments. While multiple studies investigate IMTP to dynamic sports assessments or changes to body composition effecting performance, to the best of the authors knowledge, no studies compare the correlation of IMTP to mass ratio to these assessments. This study aims to investigate the Relative Strength Ratio (RSR) using IMTP to mass ratios and their correlation to dynamic sports assessments. The secondary aim is to determine which correlations are strongest and provide recommendation of strength to mass thresholds should they exist.

Methods

Participants

Nineteen participants (n=19, males =14, females=5) ranging in age, height and mass (14 years±2.5, 165.5 cm±12.7, 55.4 kg±19.7) were included in this study with backgrounds from various sports as shown in Figure 1&2. Lean Body Mass (LBM) and Percent Body Fat (PBF) were 47.2kg±15.9 and 15.1%±0.08 respectively. Participants were categorized by age groups as shown in Figure 3. This study used historical data captured during assessments of athlete's abilities prior to beginning a training program. All athletes had to be part of an organized sports program with some resistance training experience, >1year.

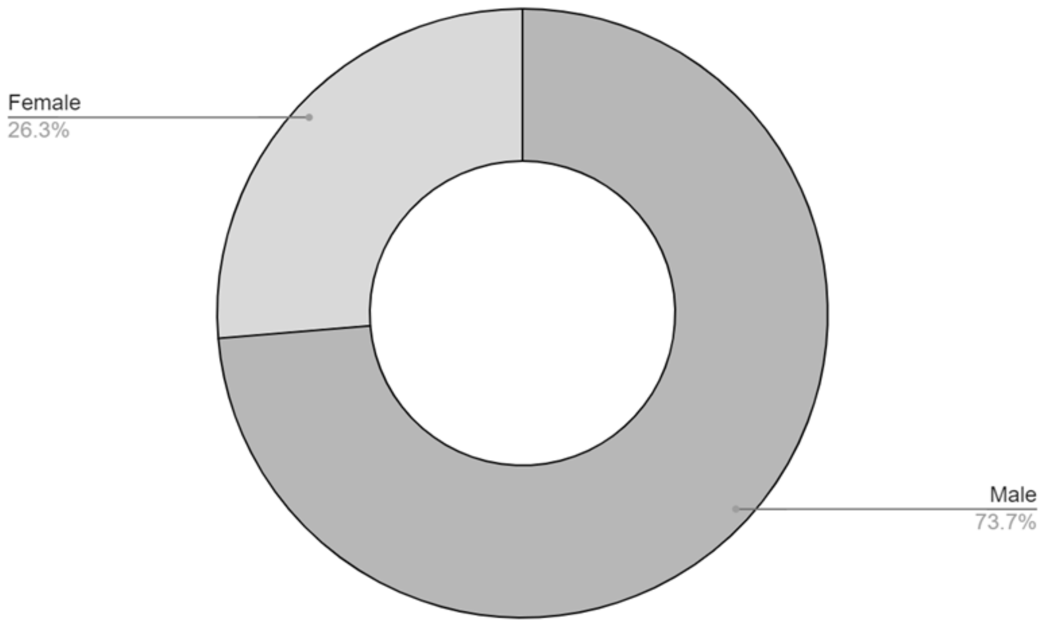

Figure 1: Gender distribution.

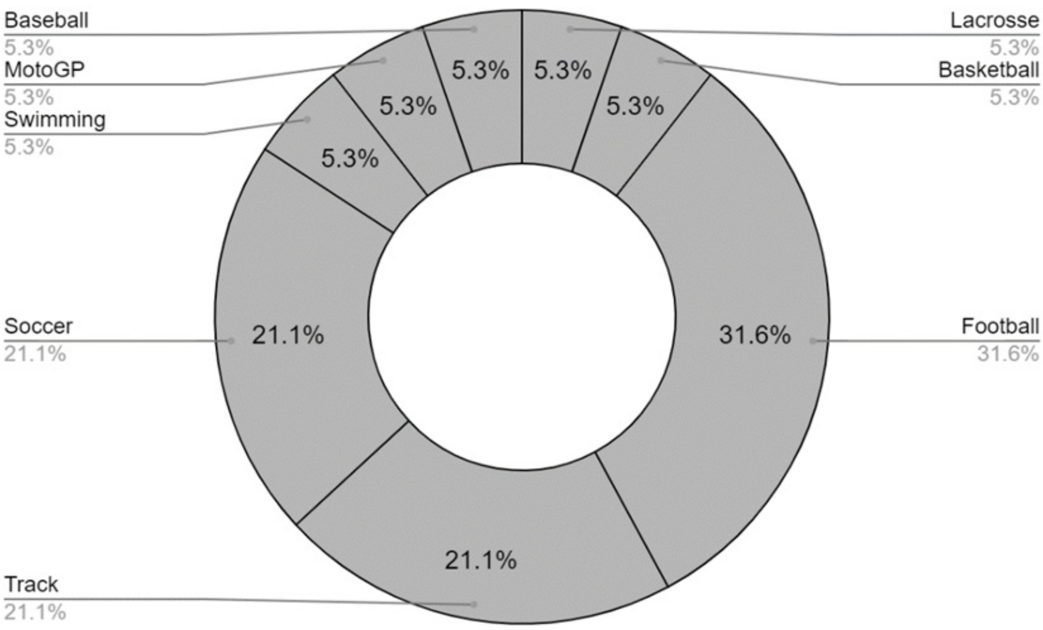

Figure 2: Sport distribution.

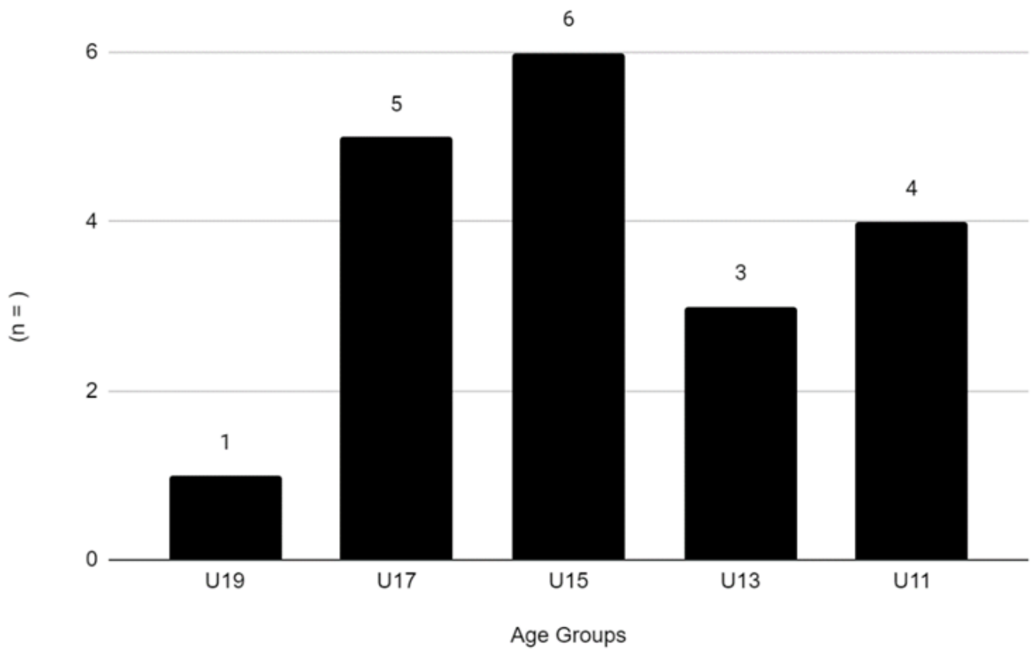

Figure 3: Age Groups separated by 2 years.

Inclusion criteria

a) Active, healthy, in a recreational sports program.

b) Some resistance training or sport training.

c) Athletes must be between 11-19 years of age.

Exclusion criteria

A. No injuries in the last six months.

B. Not in physical therapy or rehabilitation for an injury.

C. No limitations/restrictions from doctor.

D. Sedentary, no resistance or sport training.

E. Not currently on a team.

Procedures

Athletes arrived at Exsurgo Strong and Fit (Ashburn, VA) on their assessment day. Athletes were explained testing protocols and procedures. Anthropometric data was collected for each athlete. Height was captured using a portable stadiometer (PUSH

In Lab S50, InBody, Cerritos, CA). Body composition including weight, LBM, PBF, were collected via Bioimpedance Analysis (BIA) using the InBody 570 (Cerritos, CA). Multiple studies validate BIA using the InBody 570 as a reliable and practical alternative to other methods of assessing body composition [22-24]. Athletes were then given a general warm-up consisting of 3mins of cardio and low intensity squats, lunges and hinging followed by dynamic warm-up to activate and prepare for the testing lasting no longer than 10-15mins.

Testing then proceeded in the following order: $IMTP_{max}$, $IMTP_{rfd}$, CMJ, Drop Jump, 20m Sprint, COD5-10-5. Two minutes of rest was given between each assessment.

$IMTP_{max}$: An explanation and demonstration were given on how to perform the test following standardized methods [11,10]. Athletes performed three warmup efforts for five seconds followed by three seconds of rest in succession before attempting a max effort. Athletes then rested 60 seconds before performing a maximum $IMTP_{max}$ effort for a maximum of 5 seconds. Athletes were given 60 seconds of rest between each effort until the force output decreased below 250N for two consecutive repetitions. The gStrength from Exsurgo Technologies (Ashburn, VA) was used for this assessment.

$IMTP_{rfd}$: An explanation was given on how to perform the test. Athletes then proceeded to do a fast effort until two consecutive reps showed a decrease in RFD. Athletes were given 60 seconds of rest between each effort until the force output at 200ms decreased for two consecutive repetitions. The gStrength from Exsurgo Technologies (Ashburn, VA) was used for this assessment.

CMJ: An explanation and demonstration were given on how to perform the test. The athlete then did 3 counter movement jumps followed by 60 secs of rest until the max jump height is reached and 2 consecutive jumps decrease. The gFlight from Exsurgo Technologies (Ashburn, VA) was used for this assessment.

Drop jump: An explanation and demonstration were given on how to perform the test. A 30cm box was used along with a line of tape on the ground for them to target and land. The gFlight from Exsurgo Technologies (Ashburn, VA) was used for this assessment. Drop Jump Height (DRJ_h) in centimeters, Ground Contact Time (DRJ_{gct}) in milliseconds and Reactive Strength Index (DRJ_{rsi}) were captured and recorded.

20m sprint: An explanation and demonstration were given on how to perform the test. The athlete did 3 efforts with 60 seconds of rest in between until two consecutive efforts were above the fastest time. The gSprint from Exsurgo Technologies (Ashburn, VA) was used for this assessment with a split gate at 10m.

COD 5-10-5: An explanation and demonstration were given on how to perform the test. The athlete did 3 efforts with 60 seconds of rest in between until two consecutive efforts were above the fastest time. The gSprint from Exsurgo Technologies (Ashburn, VA) was used for this assessment. The finish gate was set up at the midpoint and athletes ran back and forth through the gate capturing their time.

All data was saved in the Exsurgo Performance System (EPS) from Exsurgo Technologies (Ashburn, VA) for later extraction and analysis.

Data preparation

Data was exported from the InBody and EPS and imported to Google Docs (Mountain View, CA). Data was formatted for ease of use and imported into RStudio 2022.07.2+576 (Boston, MA). Values from Google Docs were exported as "values only" to not introduce formula reference errors. Data was reviewed multiple times to ensure unaltered data was used.

Statistical analysis

Exploratory data and statistical analysis were done using RStudio. A correlation matrix was produced to assess associations between all variables. Based on the level of correlation associations and their significance, areas were further explored to assess variance. Pearson correlation coefficients were used to assess the relationship between two sets of variables and run for all variables. It should be noted that correlation does not imply a causal association between the variables investigated. Larger associations mean the two variables are related but there could be other influences [25]. Negative correlations suggest as one variable increases, the other decreases whereas positive correlations suggest as one variable increases, so does the other variable [25]. An Analysis of Variance (ANOVA) was performed to analyze age group with strength to mass ratios. Age groups were created using birthdate and separated by 2 years. An ANOVA was then performed to analyze "high, medium, and low" thresholds. These thresholds were classified using the 5^{th}, 33^{rd}, 66^{th}, 95^{th} percentile of each assessment using the quantile function in RStudio. If significant variance was found during the ANOVA, Tukey HSD was performed to identify which pairs were significant. All data was compared for normality.

Result

Descriptive statistics

Descriptive statistics for all data were gathered and analyzed as presented in Table 1. Several variables were analyzed in a correlation matrix to identify associations. These included correlations of Total Body Mass (TBM) (kg), Lean Body Mass (LBM) (kg), Percent Body Fat (PBF) (%), $IMTP_{max}$ (kg), $IMTP_{rfd}$ (kg), CMJ (cm), DRJ_h (cm), DRJ_{gct} (ms), DRJ_{rsi} (ratio), $Sprint_{10m}$ (secs), $Sprint_{20m}$ (secs) and COD_{5-10-5} (secs). The results of the analysis of these variables are presented in Figure 4&2.

Table 1: Descriptive statistics of all data gathered.

	Mean±SD	Min	Max
TBM(kg)	55.39±19.77	25.08	97.7
LBM(kg)	47.2±15.99	22.41	84.18

PBF(%)	15±8	4	32
$IMTP_{max}$(kg)	99.09±43.43	50.3	217.9
$IMTP_{rfd}$(kg)	84.56±35.69	44.3	161
CMJ(cm)	32.08±7.85	20.3	46.81
DRJ_h(cm)	32.35±9	18.84	49.89
DRJ_{gct}(ms)	278±101.03	111	493
DRJ_{rsi}	1.18±0.51	0.41	2.19
$Sprint_{10}$(sec)	2.58±0.22	2.26	2.93
$Sprint_{20}$(sec)	4.12±0.35	3.58	4.63
COD_{5-10-5}(sec)	5.29±0.39	4.57	6.1

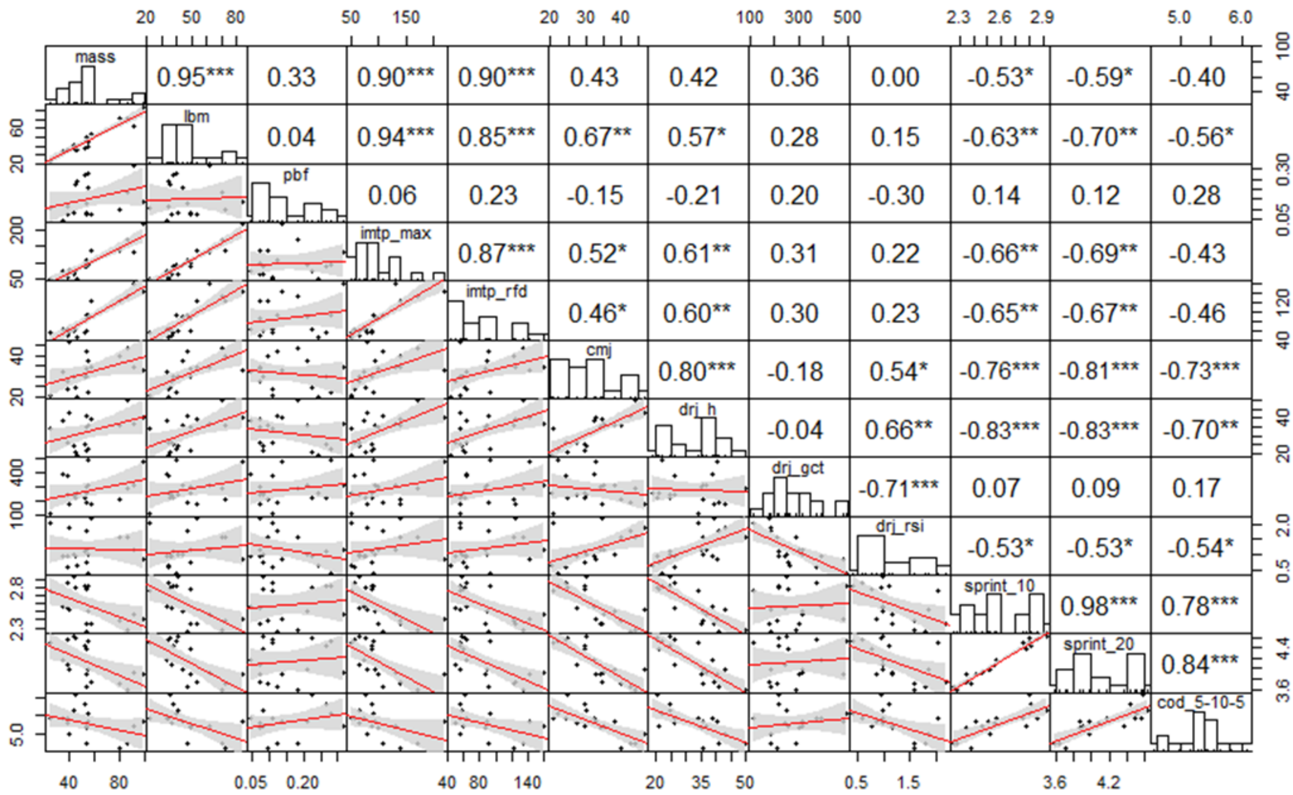

Figure 4: Correlation matrix of all variables. Significance. ***p<0.001, **p<0.01, *p<0.05.

$IMTP_{max}$

Positive correlations between $IMTP_{max}$ and TBM were very high (r=0.90) as were $IMTP_{max}$ and LBM (r=0.94). $IMTP_{max}$ showed a high correlation between $IMTP_{rfd}$ (r=0.87). Positive moderate correlations were found between $IMTP_{max}$ and CMJ (r=0.52) as well as $IMTP_{max}$ and DRJ_h (r=0.61). Positive correlation for $IMTP_{max}$ and DRJ_{gct} were low (r=0.31). Both $IMTP_{max}$ to PBF and DRJ_{rsi} were positive but negligible (r=0.06) and (r=0.22) respectively. Moderate to high negative correlations between $IMTP_{max}$ and $Sprint_{10}$ and $Sprint_{20}$ were (r=-0.66) and (r=-0.69) respectively while $IMTP_{max}$ to COD_{5-10-5} were found to be low to moderate (r=-0.43).

TBM

Investigating TBM and its association with other variables except previously reported $IMTP_{max}$, a near perfect, very high positive correlation between TBM and LBM was found (r=0.95). A very highly positive correlation between TBM and $IMTP_{rfd}$ was found as well (r=0.90). Low positive correlations were found between TBM and PBF (r=0.33), TBM and CMJ (r=0.43), TBM and DRJ_h (r=0.42) and TBM and DRJ_{gct} (r=0.36). TBM to DRJ_{rsi} was negligible (r=0.0). Moderate negative correlations were discovered between TBM and $Sprint_{10}$ (r=-0.53), TBM and $Sprint_{20}$ (r=-0.59) and TBM and COD_{5-10-5} (r=-0.40) (Table 2).

Table 2: Correlation of $IMTP_{max}$ and TBM, LBM and PBF.

Significance: ***p<0.001, **p <0.01, *p<0.05.

	$IMTP_{max}$	TBM	LBM	PBF	$IMTP_{rfd}$	CMJ	DRJ_h	DRJ_{gct}	DRJ_{rsi}	$Sprint_{10m}$	$Sprint_{20m}$	COD_{5-10-5}
IMTPmax		0.90***	0.94***	0.06	0.87***	0.52*	0.61**	0.31	0.22	-0.66**	-0.69**	-0.43
TBM			0.95***	0.33	0.90***	0.43	0.42	0.36	0	-0.53*	-0.59*	-0.4
LBM				0.04	0.85***	0.67**	0.57**	0.28	0.15	-0.63**	-0.70**	-0.56*
PBF					0.23	-0.15	-0.21	0.2	-0.3	0.14	0.12	0.28

LBM

LBM compared to $IMTP_{rfd}$ had a high positive correlation (r=0.85). Moderately positive correlations were found between LBM and CMJ and DRJ_h (r=0.67), (r=0.57) respectively. Comparing LBM and PBF, DRJ_{gct} and DRJ_{rsi}, negligible correlations were found (r=0.04), (r=0.28) and (r=0.15). Moderate to high negative correlations were found comparing LBM and $Sprint_{10}$, $Sprint_{20}$ and COD_{5-10-5} (r=-0.63), (r=-0.70), (r=-0.56).

PBF

Comparing PBF to all variables produced negligible and insignificant correlations $IMTP_{rfd}$ (r=0.23), CMJ (r=-0.15), DRJ_h (r=-0.40), DRJ_{gct} (r=0.20), DRJ_{rsi} (r=-0.30), $Sprint_{10}$ (r=0.14), $Sprint_{20}$ (r=0.12), COD_{5-10-5} (r=0.28).

RSR

Relative strength ratios were calculated by taking $IMTP_{max}$ and dividing by TBM. The mean RSR was found to be 1.78±0.32 with a minimum of 1.09 and a maximum of 2.42. Means for age groups are shown in Table 3 and plotted in Figure 5.

Table 3: RSR means by age group.

Age Group	Count (n=)	Mean RSR	SD
U11	4	1.77	0.391
U13	3	1.77	0.185
U15	6	1.78	0.441
U17	5	1.75	0.293
U19	1	1.96	NA

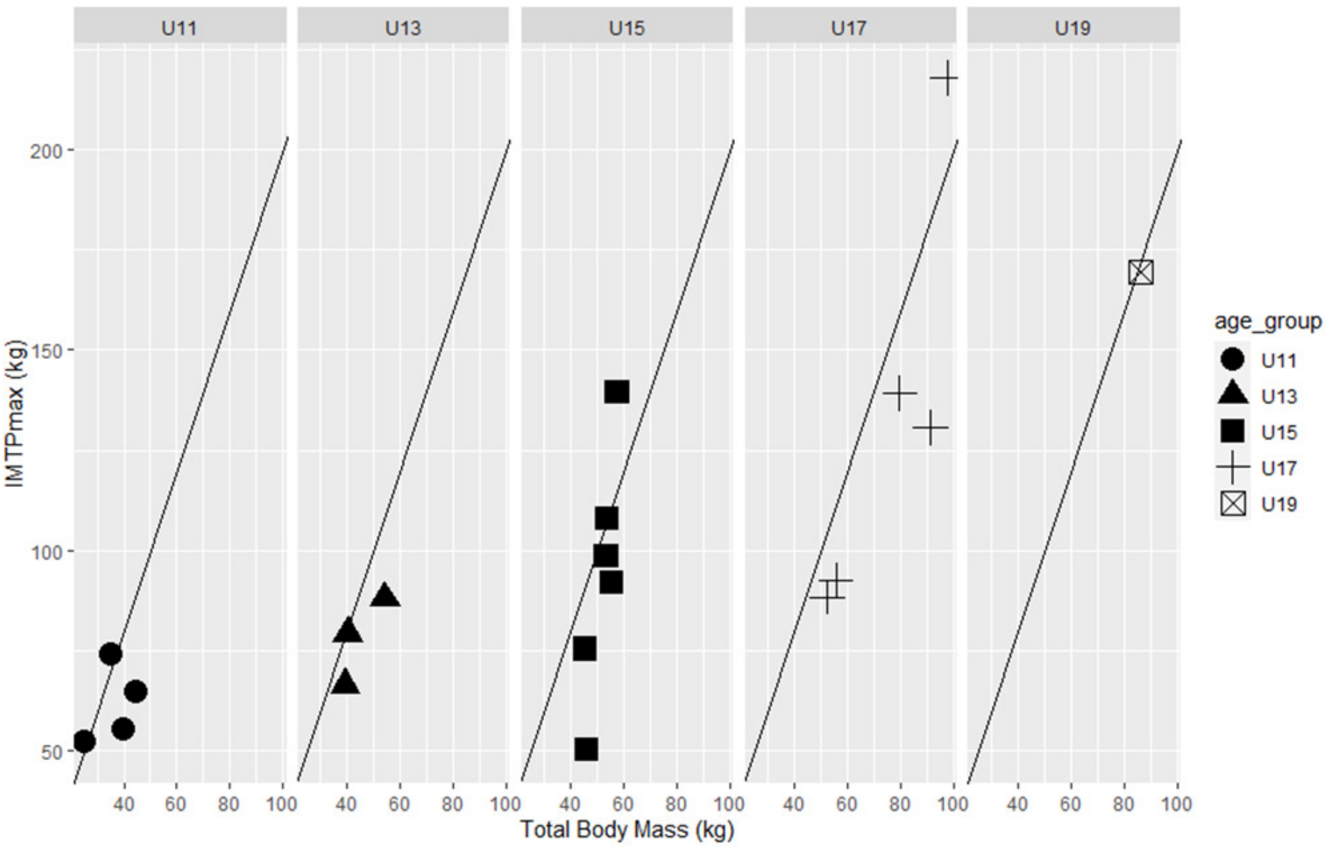

Figure 5: RSR TBM and $IMTP_{max}$ with 2:1 $IMTP_{max}$:TBM trend line.

RSR and AGE

Using the RSR previously calculated, ANOVA results of RSR and Age groups showed no significant differences (f=0.073, p=0.989). Tukey's HSD showed not pairwise variances with 95% confidence interval as shown in Figure 6.

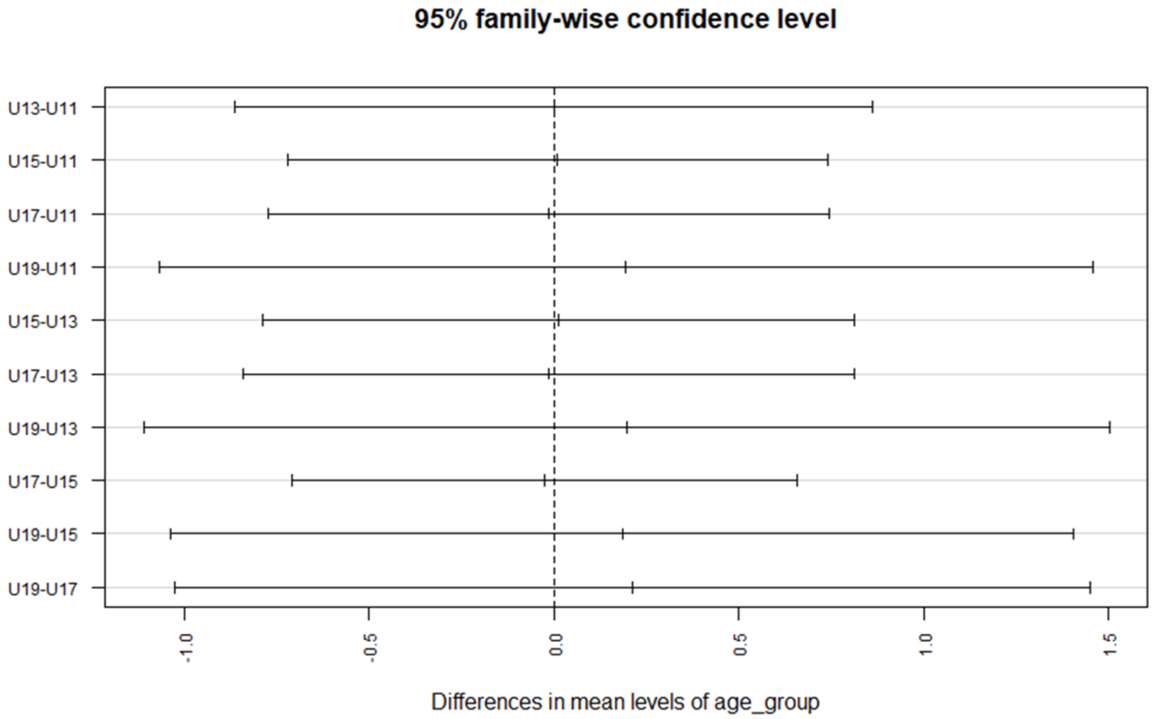

Figure 6: Plot of Tukey's HSD comparison of means between RSR and age groups.

RSR classifications

Using the calculated RSR, the values were then categorized by assigning Low to any RSR<1.5, Medium to any RSR≥1.5 or<2.0 and High to any RSR≥2.0. Using these classifications, n=4 athletes were classified as Low, n=10 was classified as Med, n=5 was classified as High. The ANOVA results of RSR to these classifications were found to be significant (f=35.96, p=<0.001). Further analysis using Tukey's HSD showed results were significant amongst each of the groups Med-Low (p<0.001), High-Low (p<0.001), and High-Med (p<0.001). The differences in means are further shown by Figure 7 as the values of each comparison of means are outside the 95% confidence interval. Means for each of the RSR classifications are shown in Table 4.

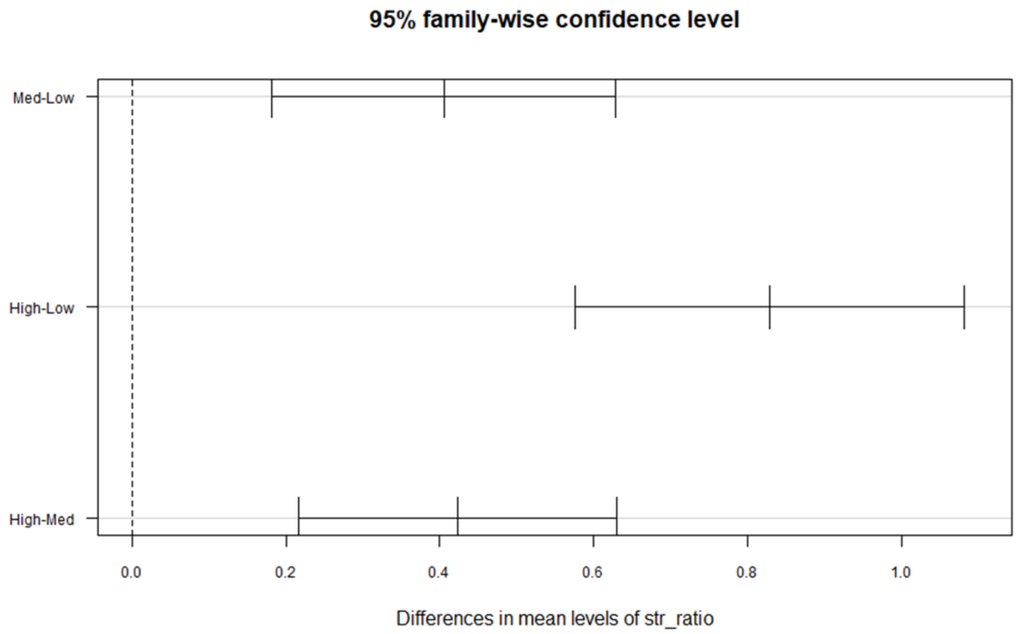

Figure 7: Plot of Tukey's HSD comparison of means between RSR and age groups.

Table 4: Mean RSR classifications by low, med and high.

RSR	Count (n=)	Mean	SD
Low	4	1.35	0.169
Med	10	1.75	0.131
High	5	2.18	0.16

RSR classifications and dynamic assessments

Using the RSR Classifications of Low, Medium and High, correlations were then analyzed for each of the groups comparing dynamic sports assessments. Results of the correlations and their significance are displayed in Table 5. High positive correlations which were significant were found for the RSR Med group in CMJ (r=0.81, p<0.01), DRJ_h (r=0.89, p<0.01), DRJ_{rsi} (r=0.83, p<0.01). High negative correlations which were significant were found for Sprint10 (r=-0.71, p<0.05) and Sprint20 (r=-0.70, p<0.05). A moderate negative correlation was found for RSR Med but the result was not significant but nearing significance (r=-0.6, p=0.066). RSR Med and DRJ_{gct} had a negligible correlation and was not significant (r=-0.26, p=0.48). The RSR Low group when correlated to the dynamic assessments showed high positive correlation but was not significant for CMJ (r=0.75, p=0.25). RSR Low and DRJ_h showed moderate correlation but was not significant (r=0.68, p=0.32). The same was found for RSR Low and DRJ_{rsi} (r=0.52, p=0.48) and RSR Low and COD5-10-5 (r=0.50, p=0.67). RSR Low and DRJ_{gct} were found to correlate low and with no significance (r=0.38, p=0.62). Both Sprint10 and Sprint20 had a negligible positive correlation with no significance to RSR Low (r=0.14, p=0.91) and (r=0.099, p=0.94) respectively. The RSR High group, when correlated to the dynamic assessments showed negligible positive and negative correlations with no significance. RSR High and CMJ (r=-0.033, p=0.96), RSR High and DRJ_h (r=0.13, p=0.84). RSR High and DRJ_{gct} (r=0.093, p=0.88). RSR High and DRJ_{rsi} (r=0.18, p=0.77). RSR High compared to Sprint10 and Sprint20 were negligible and negatively correlated (r=-0.22, p=0.73) and (r=-0.29, p=0.63) respectively. Only COD5-10-5 had a moderate correlation but was not statistically significant (r=0.69, p=0.31) (Table 6).

Table 5: Correlation of RSR low, med and high with dynamic sports assessments.

☆: Denotes high positive/negative, statistically significant correlation.

‡: Denotes nearing significance.

	RSR Low (r,p)	RSR Med (r,p)	RSR High (r,p)
CMJ	0.75, 0.25	0.81, 0.0048☆	-0.033, 0.96
DRJ_h	0.68, 0.32	0.89, 0.00066☆	0.13, 0.84
DRJ_{gct}	0.38, 0.62	-0.26, 0.48	0.093, 0.88
DRJ_{rsi}	0.52, 0.48	0.83, 0.0029☆	0.18, 0.77
$Sprint_{10}$	0.14, 0.91	-0.71, 0.022☆	-0.22, 0.73
$Sprint_{20}$	0.099, 0.94	-0.7, 0.023☆	-0.29, 0.63
$COD_{5\text{-}10\text{-}5}$	0.5, 0.67	-0.6, 0.066‡	0.69, 0.31

Table 6: RSR classifications and dynamic sports assessments. ☆-Denotes highest in each dynamic assessment.

	RSR Low (n=4)	RSR Med (n=10)	RSR High (n=5)
CMJ(cm)	27.3±6.45	33.7±8.35☆	32.7±7.74
DRJ_h(cm)	26.6±7.50	31.4±10.1	38.8±2.67☆
DRJ_{gct}(ms)	300±57.5	273±88.5	270±159☆
DRJ_{rsi}(rsi)	0.837±0.28	1.13±0.434	1.57±0.622☆
$Sprint_{10}$(secs)	2.75±0.251	2.58±0.208	2.47±0.197☆
$Sprint_{20}$(secs)	4.36±0.397	4.11±0.345	3.98±0.347☆
$COD_{5\text{-}10\text{-}5}$(secs)	5.42±0.221	5.27±0.467	5.23±0.345☆

Discussion

The primary finding of this investigation is that RSR's affect performance as athletes with RSR_{med} (1.5-2.0) to RSR_{high} (2.0+) performed better at dynamic assessments. The secondary finding of this investigation is that thresholds do exist within this sample for RSR when compared to dynamic sports assessments. The mean RSR was 1.78±0.32 which suggests $IMTP_{max}$ could be used to assess training adaptations and progress with respect to TBM. While the data shows RSR_{high} athletes performed the best, the threshold of 1.78 RSR_{med} should be investigated in other athletes and sports specifically to determine if the thresholds still exist. As mentioned previously, athletes with an RSR_{med} or higher did perform better than those with RSR_{low} suggesting that training focused on strength alone will progress the athlete, but too much focus on strength could create a diminishing return. As RSR_{high} had very little correlation to dynamic sports performance as outlined in Table 5 but performed better than RSR_{med} as shown in Table 7, this suggests another factor could influence performance and that strength alone is not the key factor in dynamic performance assessments. An interesting aspect is the correlation of $IMTP_{max}$ and LBM (r=0.94, p<0.01) which showed higher correlations between the dynamic performance assessments than $IMTP_{max}$ and TBM (r=0.90, p<0.01). This suggests the importance of body composition with respect to optimal athlete performance. Contrary to this finding, $IMTP_{max}$ and PBF (r=0.06, p>0.5) were found to be negligible and PBF showed both negligible positive and negative correlations to dynamic performance assessments suggesting there is little effect of PBF to performance assessments. While other studies show a negative association of PBF to sports performance, they did not consider RSR as a metric [21,18].

Table 7: Calculations of IMTP based on RSR from this investigation and suggested standard. * Denotes estimated based on calculations.

		TBM	55kg
	RSR	IMTP	SQT1RM
Results	1.78	97.90kg	73.43kg*
Standard	2.5	183.33kg*	137.50kg
Difference	0.72	85.43kg	64.08kg

The results of this investigation show if RSR is Medium to High, PBF may not affect performance. This does not mean disregard PBF and body composition, but rather other factors may influence performance such as RFD and its relation to $IMTP_{max}$ and the dynamic sports assessments when considering PBF. Further research should be done investigating $IMTP_{rfd}$ and $IMTP_{max}$ to determine if a relationship exists to dynamic sports assessments. A recent systematic review reported correlations for $IMTP_{max}$ and $IMTP_{rfd}$ to dynamic sports assessments. The findings of the systematic review were compared to the results of this investigation. The CMJ in this investigation correlated to $IMTP_{max}$ (r=0.52) while the systematic review found the correlations of (r=0.81), (r=0.59 to 0.67), (r=0.588), (r=0.36), (r=0.82), (r=0.346) and (r=0.47 to -0.49) [17,19,26-31]. This suggests there is some variability in the relationship but some results are very similar to the current investigation suggesting the results of this investigation are representative of the wider population. Similar findings were found for the Sprint20 where this investigation's results were (r=-0.69), while the systematic review reported similar correlations (r=-0.619 to 0.696), (r=-0.57 to -0.69) [17,27,32]. The agreement between studies in the systematic review and this investigation reinforce the nature of the findings that RSR's do exist when taking into consideration the ratio of $IMTP_{max}$ to TBM. The strength of the correlations paired with the consistency in findings from prior research should aid practitioners in evaluating their athletes by utilizing RSR as a metric.

Additional considerations comparing the previously mentioned squat 1RM strength standard of 2.5 x TBM for elite athletes should be called into question. Using guidelines from prior research where the $IMTP_{max}$ was shown to associate with squat (r=0.866, p<0.001), deadlift (r=0.88, p<0.01), and dynamic mid-thigh pull at 30% $IMTP_{max}$ (r=0.96, p<0.01), this investigation shows RSR to be a more accurate method of assessing relative strength when compared to TBM, LBM and PBF with respect to changes in body composition and dynamic sports performance [11,12,21,18,19]. Using the current investigations findings, taking into consideration $IMTP_{max}$ to 1RM squat compared to the previous mentioned strength standards, the average mass of athletes in this investigation was 55kg±19.77. Using the mean RSR of 1.78±0.32 as the basis for calculations, the calculated $IMTP_{max}$ would be 97.9kg and the estimated squat one repetition max (1RMe) would be 73.4kg.

TBM 55kg* RSR 1.78=$IMTP_{max}$ 97.9kg

$IMTP_{max}$ 97.9 kg* 0.75=Squat 1RMe 73.4kg

Surveying athletes from this investigation with a 55kg TBM, the observed mean $IMTP_{max}$ was 92.2kg, a difference of 5.8% for the above calculated $IMTP_{max}$. Using the previously mentioned collegiate squat 1RM strength standard of 2.5xTBM, this would suggest these athletes should possess a squat 1RM of 137.5kg and potentially an $IMTP_{max}$ of 183.33kg, a difference of 49% for the $IMTP_{max}$.

TBM 55kg* RSR 2.5=Squat 1RM 137.50kg

Squat 1RM 137.50kg/0.75=estimated $IMTP_{max}$ 183.33kg

As many of the high performing athletes (RSR_{med} or RSR_{high}) in this study are on elite, competitive teams with a successful play record, yet do not possess squats of that magnitude, this investigation suggests the 2.5* TBM squat strength standard be reevaluated. With the mean age of the participants in this investigation being 14 years±2.5, the results of this investigation suggest alternative ways to assess strength and performance via RSR with respect to $IMTP_{max}$ and TBM.

Practical application

The average strength to mass ratio or Relative Strength Ratio (RSR) was found to be 1.78. Athletes above this average were the top performers in each of the categories. Practitioners should evaluate their athletes based on their $IMTP_{max}$ to TBM ratio taking into consideration lean body mass when considering alterations to training programs. It should be noted that PBF had very weak correlations to every assessment. As muscle produces force and fat does not, it is in the interest of the practitioner to aid the athlete in body composition strategies which favor an increase in strength, rate at which that strength is expressed and an increase in lean body mass where applicable. Increasing LBM could positively alter RSR without changes to strength and could increase performance [10]. With the recent advancement and accessibility in technology, as well as findings from prior studies, $IMTP_{max}$ assessments could be done in place of 1RM testing for the squat and deadlift especially for youth athletes [7,8]. Daily monitoring of athletes accumulated stress, fatigue and readiness could be done using $IMTP_{max}$ values and observed over time to see the fluctuation in $IMTP_{max}$ performance. Loading schemes could be derived from $IMTP_{max}$ testing based on the correlation to squat and deadlift taking into consideration results from the daily load monitoring [11-13].

Conclusion

Assessing athletes via relative strength ratios considering isometric force production and total body mass with respect to lean body mass and percent body fat may provide additional insight into training programming and body composition modifications to increase dynamic sports performance.

References

1. Litras Amalia (2020) Absolute vs relative strength. Grass Iron.
2. Competition rules & USAW rules addendum. Team USA.
3. Schoenfeld BJ, Grgic J, Van Every DW, Plotkin DL (2021) Loading recommendations for muscle strength, hypertrophy and local endurance: A re-examination of the repetition continuum. Sports (Basel) 9(2): 32.
4. Basil Patrick (2022) Understanding and applying relative strength standards. SimpliFaster.
5. Smith Joel, Two commonly ignored strength methods to supercharge the power athlete. Just Fly Sports.
6. (2000) 2 to 20 years: Girls body mass index-for-age percentiles.
7. Robertson RJ, Goss FL, Aaron DJ, Gairola A, Kowallis RA, et al. (2008) One repetition maximum prediction model for children using the OMNI RPE scale. Journal of Strength and Conditioning Research 22(1): 196-201.
8. Faigenbaum AD, Kraemer WJ, Blimkie CJR, Ian J, Micheli LJ, et al. (2009) Youth resistance training: Updated position statement paper from the national strength and conditioning association. Journal of Strength and Conditioning Research 23(5): S60-79.
9. National Strength & Conditioning Association (US) (2022) Miller T Nsca's guide to tests and assessments. Human Kinetics, Illinois, USA.
10. Comfort P, Dos'Santos T, Beckham GK, Stone MH, Guppy SN, et al. (2019) Standardization and methodological considerations for the isometric midthigh pull. Strength & Conditioning Journal 41(2): 7-79.
11. De Witt JK, English KL, Crowell JB, Kalogera KL, Guilliams ME, et al. (2018) Isometric midthigh pull reliability and relationship to deadlift one repetition maximum. Journal of Strength and Conditioning Research 32(2): 528-533.
12. Wang R, Hoffman JR, Tanigawa S, Miramonti AA, Monica MBL, et al. (2016) Isometric mid-thigh pulls correlates with strength, sprint and agility performance in collegiate rugby union players. The Journal of Strength & Conditioning Research 30(11): 3051-3056.
13. Haff GG, Carlock JM, Hartman MJ, Kilgore JL, Kawamori N, et al. (2005) Force-time curve characteristics of dynamic and isometric muscle actions of elite women Olympic weightlifters. Journal of Strength and Conditioning Research 19(4): 741-748.
14. Suchomel TJ, Nimphius S, Stone MH (2016) The importance of muscular strength in athletic performance. Sports Med 46(10): 419-1449.
15. James LP, Roberts LA, Haff GG, Kelly VG, Beckman EM (2017) Validity and reliability of a portable isometric mid-thigh clean pull. The Journal of Strength & Conditioning Research 31(5): 1378-1386.
16. Ripley N, McMahon J (2022) Validation of a commercially available strain gauge against a series of known loads using a short time approach. ISBS Proceedings Archive 40(1): 591.
17. Lum D, Haff GG, Barbosa TM (2020) The relationship between isometric force-time characteristics and dynamic performance: A systematic review. Sports (Basel) 8(5): 63.
18. Darrall Jones JD, Jones B, Till K (2015) Anthropometric and physical profiles of English academy rugby union players. The Journal of Strength & Conditioning Research 29(8): 2086-2096.
19. Dos'Santos T, Thomas C, Comfort P, McMahon JJ, Jones PA (2017) Relationships between isometric force-time characteristics and dynamic performance. Sports (Basel) 5(3): 68.
20. West DJ, Owen NJ, Jones MR, Bracken RM, Cook CJ, et al. (2011) Relationships between force-time characteristics of the isometric midthigh pull and dynamic performance in professional rugby league players. J Strength Cond Res 25(11): 3070-3075.
21. Miller TA, White ED, Kinley KA, Congleton JJ, Clark MJ (2002) The effects of training history, player position and body composition on exercise performance in collegiate football players. J Strength Cond Res 16(1): 44-49.
22. Sirirat R, Heskey C, Wilson C, Bitok E, Jones J, et al. (2020) A comparison of body composition measurements between bioelectrical impedance analysis (InBody 570) and air displacement plethysmography (BOD POD®). Current Developments in Nutrition 4(2): 1689.
23. Miller RM, Chambers TL, Burns SP, Godard MP (2016) Validating in body® 570 multi-frequency bioelectrical impedance analyzer versus DXA for body fat percentage analysis. Medicine & Science in Sports & Exercise 48(5): 991.
24. McLester CN, Nickerson BS, Kliszczewicz BM, McLester JR (2020) Reliability and agreement of various in body composition analyzers as compared to dual-energy x-ray absorptiometry in healthy men and women. J Clin Densitom 23(3): 443-450.
25. Schober P, Boer C, Schwarte LA (2018) Correlation coefficients: Appropriate use and interpretation. Anesthesia & Analgesia 126(5): 1763-1768.
26. Stone MH, Sands WA, Carlock J, Callan S, Dickie D, et al. (2004) The importance of isometric maximum strength and peak rate-of-force development in sprint cycling. Journal of Strength and Conditioning Research 18(4): 878-884.
27. Townsend JR, Bender D, Vantrease WC, Hudy J, Huet K, et al. (2019) Isometric midthigh pull performance is associated with athletic performance and sprinting kinetics in division i men and women's basketball players. Journal of Strength and Conditioning Research 33(10): 2665-2673.
28. Nuzzo JL, McBride JM, Cormie P, McCaulley GO (2008) Relationship between countermovement jump performance and multi joint isometric and dynamic tests of strength. Journal of Strength and Conditioning Research 22(3): 699-707.
29. Kraska JM, Ramsey MW, Haff GG, Fethke N, Sands WA, et al. (2009) Relationship between strength characteristics and unweighted and weighted vertical jump height. International Journal of Sports Physiology and Performance 4(4): 461-473.
30. Kawamori N, Rossi SJ, Justice BD, Haff EE, Pistilli EE, et al. (2006) Peak force and rate of force development during isometric and dynamic mid-thigh clean pulls performed at various intensities. Journal of Strength and Conditioning Research 20(3): 483-491.
31. Bailey C, Sato K, Alexander R, Chiang CY, Stone MH (2013) Isometric force production symmetry and jumping performance in collegiate athletes. Journal of Trainology 2(1): 1-5.
32. Thomas C, Comfort P, Chiang CY, Jones PA (2015) Relationship between isometric mid-thigh pull variables and sprint and change of direction performance in collegiate athletes. Journal of Trainology 4(1): 6-10.