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Different Body Partialization Procedures Considering Maximum Strength and Explosiveness: Factorial Analysis Approach

Diferentes Procedimientos de Parcialización Corporal Considerando Fuerza Máxima y Explosividad: Enfoque de Análisis Factorial

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SUMMARY: The aim of this study was to determine the sensitivity of different methods of partialization, in terms of different body component indices in relation to indicators of strength and explosiveness. The research involved 187 subjects who were divided into two groups based on sex. This research consisted of measuring body composition characteristics by multichannel bioimpedance analysis (BIA) InBody 720, as well as contractile characteristics of different muscle groups with tenziometric Dinamometry method. Based on the results of the factor analysis we found that regardless of the sex the most sensitive variable for partialization of absolute body isometric strength variable (ABiS) is partialization by allometric scaling (0.964 for females and 0.947 for males explained factor variance). However, in the case of absolute body isometric explosiveness (ABiE), the results of this study have demonstrated that partialization relative to skeletal muscle mass according to the body longitudinality – skeletal muscle mass index (SMMI) is the methodological choice disregarding the sex (0.982 for females and 0.980 for males explained factor variance). The results of the study have shown that for the purpose of scaling the maximal strength relative to body composition, the allometric method can be considered as a choice, while for the partialization of maximal isometric explosiveness skeletal muscle mass index is the best choice insensitive of the sex.

KEY WORDS: Body composition; Body strength index; Isometric contraction; Muscle force; Assessment.

INTRODUCTION

It is generally known that muscular strength and explosiveness directly affect the physical performance. Muscle strength is usually defined as the maximum force or torque of a particular muscle group developed during maximal voluntary contraction under a given set of conditions (Jaric, 2003). Some measurement procedures (tests) in addition to maximum strength and torque, also include rate of force development (RFD), which refers to the muscle's ability to develop maximum force in a shorter period of time (Wilson & Murphy, 1996; Andersen & Aagaard, 2006; Haff *et al*., 2015; Aravena-Sagardia *et al*., 2021; Krzyszkowski *et al*., 2022).

Today's technology allows us to measure the contractile characteristics of the most important muscle groups that relate to maximum strength, explosiveness, power, endurance, etc., as well as precise measurement of body composition, where absolute protein and muscle measurements can be defined along with segmental data (Kukic *et al*., 2018; Aravena-Sagardia *et al*., 2021).

Muscle strength can be measured during different types of contraction (concentric, eccentric and isometric). One of the most commonly applied is the assessment of maximum strength in isometric conditions. Isometric testing has the same advantages considering the test procedure compared to the dynamic testing conditions, mainly by the safer and faster procedure of testing and isometric testing is sufficiently informative and represents the basic contractile ability of the muscles in a dynamic effort regime (Lum *et al*., 2020).

Allometric partialization implies partialization by body height and body volume (Jaric, 2002). In addition, it

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represents the most common approach in assessing the relationship between different muscle groups' strength and selected indices of body size (Jaric *et al*., 2005). There are a lot of studies that examined partialization methods in relation to maximum strength, regardless of sex (Vanderburgh *et al*.,1995; Jaric *et al*., 2002; Nedeljkovic *et al*., 2009a). However, there are still no studies that examined the phenomenon of selected indices of body composition considering body size relation and explosiveness. Accordingly, this study aimed to determine the sensitivity of different methods of partialization, in terms of different body component indices concerning indicators of strength and explosiveness measured in isometric conditions.

MATERIAL AND METHOD

This study was conducted using a non-experimental design in laboratory setting. Body composition was measured using multiple bioelectrical impedance, while contractile characteristics of muscle strength were measured using tensiometric dynamometry under maximal isometric voluntary contraction. The research was conducted in accordance with the Declaration of Helsinki, as well as with the approval of the Ethics Committee of the Faculty of Sports and Physical Education, University of Belgrade (484/2).

Participants. The research was realized on a total sample of 187 healthy, adult subjects, 75 of which were females (age = 23.02 ± 3.74 years, body height = 169.9 ± 7.14 cm, body mass = 64.14 ± 9.62 kg, body mass index = 22.13 ± 2.41 kg/m^2) and 112 males (age = 24.4 ± 4.8 years, body height = 184.2 ± 7.4 cm, body mass = 84.0 ± 13.5 kg, body mass index = 24.65 ± 2.93 kg/m^2). All participants were normally physically active people and students of Belgrade University.

Testing procedures. Body height was measured using an anthropometer (SECA 220; Seca, Ltd., Hamburg, Germany), according to a standardized procedure. To measure body composition, a multi-channel multi-segment bioimpedance - InBody 720 (Biospace Co., Seoul, Korea) was used, following the procedure described earlier (Dopsaj *et al*., 2020a). The contractile muscle characteristics, including hand flexors for left and right arm (Hand Grip test - HGL and HGR, respectively), plantar flexors (Plantar Flexor test - IPF), leg extensors (Isometric Leg Extension test - ILE), and back extensors (Isometric Deadlift test - IDL), were assessed using standardized testing procedures and protocol described earlier (Jaric, 2002; Majstorovic *et al*., 2020, 2021). All measurements were carried out at the Faculty of Sports and Physical Education, University of Belgrade, in the methodical research laboratory.

Table I. Calculations for indexed variables.

Variable	Calculation	Unit
ABiS_BM	ABiS (N) / BM (kg)	N/kg
ABiS_SMM	ABiS (N) / SMM (kg)	N/kg
ABiS_BMI	ABiS (N) / BMI (kg/m^2)	N/kg/m^2
ABiS_SMMI*	ABiS (N) / SMMI (kg/m^2)	N/kg/m^2
$ABiS_{-al\,bm}$	ABiS (N) ^ 0.667	Arbitrary unit
ABiE_BM	ABiE (N/s) / BM (kg)	N/s/kg
ABiE_SMM	ABiE (N/s) / SMM (kg)	N/s/kg
ABiE_BMI	ABiE (N/s) / BMI (kg/m^2)	N/s/kg/m^2
ABiE_SMMI*	ABiE (N/s) / SMMI (kg/m^2)	N/s/kg/m^2
$ABiE_{-al\,bm}$	ABiE (N/s) ^ 0.667	Arbitrary unit

*SMMI is calculated using the formula SMM/BH2 (kg/m^2) according to Dopsaj *et al*. (2020b).

Variables. Criterion variables in terms of the tested parameters of contractility (isometric maximal strength – F_{max} (tested by classical isometric method) and maximal isometric explosiveness - RFD_{max} (tested by impulse isometric method) were obtained by summing up all the results from the tested muscle groups. The following formula was used: ABiS (absolute body isometric strength) = F_{max}HGL + F_{max}HGR + F_{max}IDF + FmaxILE + F_{max}IPF; i.e for maximal isometric explosiveness: ABiE (absolute body isometric explosivity) = RFD_{max}HGL + RFD_{max}HGR + RFD_{max}IDF + RFD_{max}ILE + RFD_{max}IPF. For independent variables, all relativizations were calculated using different body composition elements, as well as: body mass (BM), skeletal muscle mass (SMM), body mass index (BMI), skeletal muscle mass index (SMMI), together with allometrically scaled variables, for which a standardized procedure was used (Jaric *et al*., 2005). In that way, we made relativization considering the contractile potential mass of the body (BM and SMM), body voluminosity characteristics (BMI), body longitudinal characteristics (SMMI), and allometric aspects of body characteristics (Table I).

Relative values of ABiS and ABiE were calculated in the following way (Table I).

Statistical Procedures. Descriptive statistics was used to calculate the measurements of central tendency: mean, confidence interval at the level of 95% and measureof dispersion: standard deviation (SD) and coefficient of variation (CoV). The reliability of the tests was assessed by the inter-class correlation coefficient (ICC), whose values were defined as: low ICC<0.5, moderate ICC=0.5-0.75, high ICC=0.76-0.90 and excellent reliability ICC>0.9 (Koo & Li, 2016). The normality of the data was determined by the Kolmogorov-Smirnov test (p>0.05). Additionally, Bartlett's test of sphericity (p=0.01) and the Kaiser-Meyer-Olkin (KMO) test of sample adequacy were used to check all assumptions for conducting factor analysis. Then, factor analysis, confirmatory type with Varimax rotation, was used to extract the main factors. The first extracted variable as the first extracted factor represented methodologically the most important variable for body partialisation. All statistical analyses were performed using the IBM SPSS 25 (IBM Corp., 2017) and Microsoft Excel (Microsoft Corp., 2018).

RESULTS

Table II shows the descriptive statistics for the original and scaled variables of maximal strength and explosiveness in relation to sex. Based on the results, it can be claimed that the level of homogeneity is high, as the coefficient of variation (CoV%) ranges from 15.63 for the variable ABiS_SMM to 25.34 for the variable ABiE_BMI in women and from 12.93 for the variable ABiS_SMMI to 20.93 for the variable ABiE_BMI in man.

Table III shows the reliability of all tests performed in this study, based on the inter-class correlation coefficient. According to the results shown in Table III, all tests show moderate to high levels of reliability (ICC=0.606-0.986).

Table II. Descriptive statistics for females and males.

			FEMALES				
				95% Conf. Int.		*K-S*	
	Mean	*SD*	*CoV%*	*Lower*	*Upper*	*Z*	*p*
ABiS	5726.0	1181.8	20.64	5454.6	5998.4	0.072	0.200
ABiS_BM	89.6	15.5	17.28	86.1	93.2	0.045	0.200
ABiS_SMM	212.4	33.2	15.63	204.7	220.0	0.065	0.200
ABiS_BMI	258.9	48.1	18.58	247.9	270.1	0.092	0.190
ABiS_SMMI	613.3	99.1	16.16	590.5	636.1	0.061	0.200
ABiS_allom	714.5	126.7	17.73	685.4	743.7	0.054	0.200
ABiE	32449.0	8944.7	27.56	30391.4	34507.6	0.080	0.200
ABiE_BM	1194.0	262.2	21.96	1133.7	1254.3	0.069	0.200
ABiE_SMM	1193.9	262.1	21.95	1133.7	1254.3	0.069	0.200
ABiE_BMI	1463.8	370.9	25.34	1378.5	1549.2	0.118	0.011
ABiE_SMMI	3460.3	807.1	23.32	3274.6	3645.9	0.096	0.087
ABiE_allom	4037.9	1000.5	24.78	3807.7	4268.2	0.096	0.087
			MALES				
				95% Conf. Int.		*K-S*	
	Mean	*SD*	*CoV%*	*Lower*	*Upper*	*Z*	*p*
ABiS	8352.8	*1537.2*	*18.41*	*8065.1*	*8640.6*	0.06	0.200
ABiS_BM	103.9	14.9	14.34	98.2	103.7	0.06	0.200
ABiS_SMM	203.8	27.3	13.39	198.7	208.9	0.04	0.200
ABiS_BMI	341.9	51.3	15.01	332.3	342.1	0.03	0.200
ABiS_SMMI	689.9	89.2	12.93	673.3	706.6	0.10	0.003
ABiS_allom	918.2	130.1	14.16	893.8	942.5	0.06	0.200
ABiE	47997.6	11021.1	22.96	45934.1	50061.3	0.06	0.200
ABiE_BM	1162.6	237.7	20.45	1118.1	1207.1	0.09	0.200
ABiE_SMM	1207.1	237.7	19.69	1118.1	1207.1	0.09	0.018
ABiE_BMI	1949.8	408.1	20.93	1873.5	2026.3	0.06	0.200
ABiE_SMMI	3937.6	786.7	19.97	3790.4	4084.9	0.07	0.099
ABiE_allom	5239.4	1079.3	20.59	5037.3	5441.5	0.06	0.200

Table III. Interclass correlation coefficients.

	CLASSIC CONTRACTION		IMPULSE CONTRACTION	
VARIABLE	ICC (Single Measures)	ICC (Average Measures)	ICC (Single Measures)	ICC (Average Measures)
F_{max}_HGR	.932	.965	.937	.978
F_{max}_HGL	.952	.976	.967	.983
F_{max}_IDL	.936	.967	.954	.976
F_{max}_ILE	.906	.951	.908	.952
F_{max}_IPF	.735	.893	.852	.945
RFD_HGR	.959	.979	.960	.986
RFD_HGL	.844	.915	.965	.988
RFD_IDL	.606	.755	.668	.801
RFD_ILE	.649	.787	.765	.867
RFD_IPF	.857	.947	.951	.975

Factor analysis for females (Table IV) extracted only one factor for ABiS and ABiE variables, which explain 87.683 % and 93.503 % of the total variance, respectively. These results indicate that the observed variables belong to the same measurement space.

Similarly, factor analysis for males (Table V) revealed that only one factor was identified for ABiS and ABiE variables, explaining 86.966 % and 93.636 % of the total variance, respectively.

Table IV. Factor pattern matrix with communalities for females.

Variable	*Factor 1*	*Communalities*
ABiS_$_{al\,bm}$	.964	.929
ABiS_BM	.949	.900
ABiS_BMI	.941	.885
ABiS_SMMI	.935	.874
ABiS_SMM	.892	.795
Sum of squared loadings	4.384	
Cummulative variance (%)	87.683	
ABiE_SMMI	.982	.963
ABiE_$_{al\,bm}$	.969	.939
ABiE_BM	.968	.937
ABiE_SMM	.968	.937
ABiE_BMI	.948	.899
Sum of squared loadings	4.675	
Cummulative variance (%)	93.503	

Table V. Factor pattern matrix with communalities for males.

Variable	*Factor 1*	*Communalities*
ABiS_$_{al\,bm}$	.947	.897
ABiS_BM	.944	.891
ABiS_BMI	.939	.882
ABiS_SMMI	.936	.876
ABiS_SMM	.896	.803
Sum of squared loadings	4.348	
Cummulative variance (%)	86.966	
ABiE_SMMI	.980	.960
ABiE_$_{al\,bm}$	.969	.939
ABiE_BM	.967	.935
ABiE_SMM	.967	.935
ABiE_BMI	.956	.913
Sum of squared loadings	4.682	
Cummulative variance (%)	93.636	

DISCUSSION

Based on the results, we can claim that regardless of sex the most sensitive variable for partialisation of F_{max}, from the aspect of overall body strength, is partialisation by allometric scaling, because the structure of the factors showed that ABiS_allom is the first isolated factor at the level of 0.964 for females and 0.947 for males (Tables IV and V). In other words, with respect to all the other partialization methods used in this research, the allometric method was proved to be the most representative, i.e. and most discriminative. These data are in accordance with previous research that dealt with partialization of strength tests in relation to morphological space, and it can be determined that this method is generally, as a methodological procedure, the most representative (Jaric *et al*., 2005).

On the other hand, regarding the normalization of RFD_{max}, from the aspect of basic body explosivity, results clearly show that partialization by musculoskeletal mass index method is the most sensitive, regardless of the sex, since the structure of factors showed that ABiE_SMMI is the most important variable in single isolated factor at the level of 0.982 for females and 0.980 for males (Tables IV and V). These findings imply that skeletal muscle mass per body height is the most sensitive method of partialization of isometric explosivity. The most probable explanation for the given results is that explosivity requires rapid muscle contractions, in which cross-sectional area has a smaller role than the length of the muscle. One of the main factors that influence the ability of a muscle to show strength relatively quickly is the length of the levers, which is a function of body height, and that represents longitudinal characteristics of the body. Longer limbs create a greater moment arm and thus greater torque for the same amount of force, which can lead to a more rapid force generation. Also, it can be speculated that taller people have longer muscles and hence more sarcomeres in series which allows for a more efficient expression of force (Nedeljkovic *et al*., 2009b). Andersen & Aagaard (2006) showed in their study that the force in maximal voluntary contraction (MVC) is strongly related to RFD in the late phase, so factors such as muscle length and architecture can influence RFD (Maffiuletti *et al*., 2016). Also, recently published research where dynamic and isometric tests are compared showed a moderate to strong statistical correlation between those two contractile work regimes, where is suggested that isometric force-time characteristics (RFD_{max}) provide insights into the rapid force production capability of human subjects which give acumen into dynamic performance capabilities (Lum *et al*., 2020; Ferná Ortega *et al*., 2022).

One of the limitations of this study could be that compound and single-joint exercises were grouped to form a strength index, whereas it would have been better to investigate them separately. Future studies might be conducted using segmental body composition analysis to scale respective upper/lower body exercises. Additionally, they could address factors such as current female hormonal status and fiber composition.

CONCLUSION

The results have shown that for the purpose of scaling the results of maximal strength relative to body composition, the allometric method can be considered as a definitive methodological choice for both sexes. However, in the case of partialization of explosive isometric force, the results of this study have demonstrated that partialization relative to skeletal muscle mass according to the body longitudinality – skeletal muscle mass index (SMMI) is the methodolical choice regardlee of sex.

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RESUMEN: El objetivo de este estudio fue determinar la sensibilidad de distintos métodos de parcialización, en términos de diferentes índices de componentes corporales en relación a los indicadores de fuerza y explosividad. En la investigación participaron 187 sujetos que se dividieron según el sexo en dos grupos. Esta investigación consistió en medir las características de composición corporal mediante análisis de bioimpedancia multicanal (BIA) InBody 720, así como las características contráctiles de diferentes grupos musculares con el método de Dinamometría tenciométrica. Con base en los resultados del análisis factorial, encontramos que, independientemente del sexo, la variable más sensible para la parcialización de la variable de fuerza isométrica corporal absoluta (ABiS) fue la parcialización mediante escala alométrica (0,964 para las mujeres y 0,947 para los hombres). Sin embargo, en el caso de la explosividad isométrica corporal absoluta (ABiE), los resultados de este estudio han demostrado que la parcialización relativa a la masa del músculo esquelético según la longitudinalidad del cuerpo – índice de masa del músculo esquelético (SMMI) es la opción metodológica sin tener en cuenta el sexo (0,982 para las mujeres y 0,980 para los hombres). Los resultados del estudio han demostrado que para escalar la fuerza máxima en relación con la composición corporal, el método alométrico puede considerarse como una opción, mientras que para la parcialización de la explosividad isométrica máxima, el índice de masa del músculo esquelético es la mejor opción independiente del sexo.

PALABRAS CLAVE: Composición corporal; Índice de fuerza corporal; Contracción isométrica; Fuerza muscular; Evaluación.

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