ISB 2013 BRAZIL
XXIV CONGRESS OF THE INTERNATIONAL SOCIETY OF BIOMECHANICS
XV BRAZILIAN CONGRESS OF BIOMECHANICS

TRUNK INERTIAL PARAMETERS OF ELITE MALE AND FEMALE SWIMMERS: ANALYSIS USING DXA AND ESTIMATION OF ERRORS FROM INDIRECT ESTIMATION METHODS

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SUMMARY

The study aimed to compare the inertial properties of the trunk segment between elite swimmers and non-competitive subjects computed using the DXA scanner and to estimate the errors when applying indirect estimation methods to compute the trunk inertial parameters.

The mass, centre of mass position in the frontal plane and the moment of inertia about the sagittal axis of the trunk segment were computed for 10 elite male swimmers, 8 elite female swimmers and 10 young adult Caucasian males using DXA. Each inertial parameter was compared group wise through analysis of variance (ANOVA). A two-way (estimation method x subject group) mixed analysis of variance (SPANOVA) compared the magnitude of errors when using five of the most popular indirect estimation methods, having DXA as the criterion measure. The study showed that no indirect estimation method was suitable for calculating BSIP of elite swimmers, when compared to results from the DXA scanner.

INTRODUCTION

Achieving accurate body segment inertial parameters (i.e., mass, centre of mass position and moments of inertia about the principal axes) is important in human motion analysis. Direct estimation methods via medical imaging technology can be expensive, time-consuming and may expose subjects to considerable radiation. Indirect estimation methods apply sets of equations to compute the inertial parameters using the subject's anthropometry, and are more widely used. However, it has been shown that indirect estimation methods may provide large errors when applied to subjects with different morphology, race, gender and age of the cohort from which the equations were devised [1].

As elite athletes have specific anthropometric characteristics suited to their activity due to morphological optimization [2], inertial properties derived from indirect estimation methods can be expected to be inaccurate. This is most critical for the trunk, which has great fluctuation in tissue composition between different populations and is most prone to variation in inertial properties [3].

Therefore, the study explored differences in the trunk inertial parameters between elite swimmers and non-athletes, and compared the magnitude of the errors when using popular indirect estimation methods for each population.

METHODS

Ten male and 8 female elite swimmers, and 10 young adult Caucasian males were recruited for this study. The whole body was scanned with the GE Lunar DXA scanner. A day-pass license agreement was arranged between the University of Western Australia and General Electric Company Healthcare Division (GEHC) to enable access to the areal density data so its relationship with the pixel color intensity of the DXA scan image provided could be computed [4]. Then, the mass, centre of mass position in the frontal plane (from the mid-hip point) and the moment of inertia about the sagittal axis of the trunk were obtained using the equations found in [5].

Anthropometry of the trunk was used as predictors for five indirect estimation methods derived from cadavers or living subjects analyzed with the gamma ray scanner (Table 1). Descriptions of the methods are found in Rossi [6].

Table 1: Characteristics of each estimation method.

Method	Type	Mathematical model
C	Cadaver-based	Regression equation
Y	Cadaver-based	Geometric modeling
Z1	Living subjects	Regression equation
Z2	Living subjects	Regression equation
Z3	Living subjects	Geometric modeling

Each inertial parameter was compared across subject groups through analysis of variance (ANOVA, $p<.05$). The absolute errors for each indirect estimation method were obtained using DXA as the criterion measure. A two-way (estimation method x subject group) mixed analysis of variance (SPANOVA, $p<.05$) was used to compare the errors for each inertial parameter.

RESULTS AND DISCUSSION

Table 2 shows the means and standard deviations of all trunk inertial parameters for each cohort and estimation method. From ANOVA, female swimmers recorded lower mass, centre of mass position and moment of inertia levels than the other two groups ($p<0.05$); male swimmers reported greater trunk mass than the other two groups ($p<0.05$). The SPANOVA showed interactions between factors for the trunk mass and moment of inertia and errors for trunk mass were significantly greater in female swimmers ($p<0.05$). Centre of mass errors are more influenced by the estimation method used than the cohort group being analyzed (Fig 1). None of the indirect estimation methods consistently had errors lower than 5% for all groups and inertial properties or consistently performed better than the others.

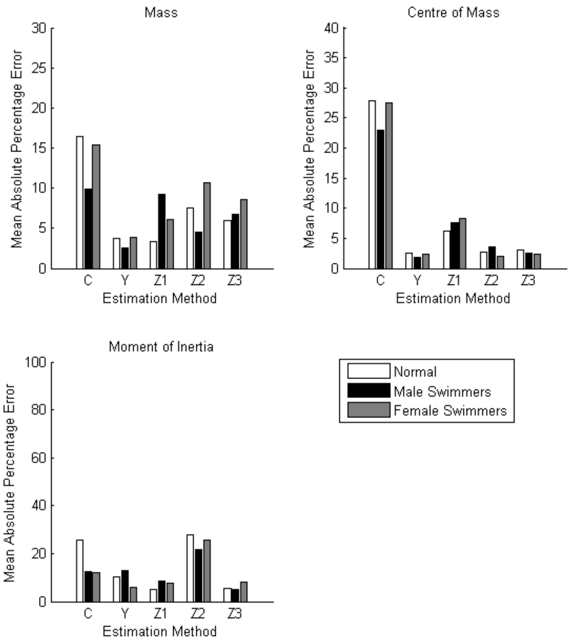

Figure 1: Mean absolute percentage error of the trunk inertial parameters.

CONCLUSIONS

One should avoid using indirect estimation methods when computing inertial parameters of the trunk of morphologically optimized populations such as elite swimmers. Future work should investigate the effects of inaccurate body segment inertial parameters in the calculation of joint dynamics of elite athletes performing specific techniques or maneuvers.

ACKNOWLEDGEMENTS

The authors would like to thank prof. Jim Dowling for his support and valuable suggestions, and to the GEHC for providing the day pass agreement.

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Table 2: Mean (SD) values for each trunk inertial parameter according to group and estimation method.

		Estimation Method					
Parameter	**Group**	**C**	**Y**	**Z1**	**Z2**	**Z3**	**DXA**
Mass (Kg)	Adult Male	39.72	34.10	33.02	36.05	32.07	34.08
		(3.64)	(3.29)	(2.95)	(3.07)	(2.61)	(2.57)
	Male Swimmers	43.04	38.91	35.55	37.68	36.52	39.14
		(4.89)	(4.46)	(4.20)	(3.72)	(3.96)	(4.02)
	Female Swimmers	32.80	27.48	26.71	31.52	26.02	28.45
		(2.58)	(2.54)	(2.03)	(2.70)	(2.43)	(2.09)
CoM (cm)	Adult Male	35.70	27.29	26.18	28.42	28.36	27.96
		(0.92)	(0.83)	(0.55)	(1.32)	(0.73)	(1.08)
	Male Swimmers	37.89	30.27	28.47	31.94	30.11	30.81
		(1.32)	(0.99)	(1.21)	(1.11)	(1.05)	(0.89)
	Female Swimmers	34.47	26.48	24.78	27.16	27.39	27.02
		(1.62)	(1.13)	(1.38)	(1.13)	(1.29)	(0.89)
MoI (Kg·cm^2)	Adult Male	16595.16	14500.71	13523.39	16840.92	13142.09	13239.06
		(2574.00)	(1886.73)	(1473.89)	(1598.89)	(1762.19)	(1838.08)
	Male Swimmers	20323.68	20276.15	16550.85	21742.87	17157.06	17958.63
		(4132.74)	(3149.84)	(2460.68)	(2860.52)	(2750.40)	(2773.83)
	Female Swimmers	12013.65	10937.66	9868.27	13467.26	10095.63	10727.80
		(2221.96)	(1724.73)	(1101.34)	(1916.16)	(1533.64)	(1552.61)