

ANTHROPOMETRIC AND STRENGTH CHARACTERISTICS OF RUGBY PLACE KICKERS

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The musculoskeletal demands of rugby place kicking are of interest to coaches from both a performance and an injury perspective. Specific musculoskeletal model inputs are required to accurately investigate these demands. This study determined selected anthropometric and strength characteristics of professional and amateur place kickers from photo-based measurements and vertical jumps. All segmental inertia characteristics were similar between the two groups aside from the torso moment of inertia. Professional players displayed superior jump strength measures compared with the amateurs. The kickers' inertia and strength characteristics also differed from commonly used values obtained from physically active males and male soccer players. Careful consideration of input parameters is required when developing musculoskeletal models of rugby kickers.

KEY WORDS: musculoskeletal modelling, rugby union, segmental inertia data, vertical jumping.

INTRODUCTION: Rugby Union (rugby) is a global sport with over 100 member nations. Place kicking is a key component of success; 45% of the total points scored in a recent sample of 582 international rugby matches came from place kicks (Quarrie & Hopkins, 2015). The techniques used by place kickers are therefore of considerable interest and recent studies have investigated specific technical aspects from a performance perspective (e.g. Bezodis et al., 2007; Cockcroft and van den Heever, 2016; Sinclair et al., 2014). However, in addition to performance outcome, the risk of injury is also an important consideration for rugby place kicking coaches (Bezodis & Winter, 2014). Research is therefore needed which considers the musculoskeletal demands of rugby place kicking. The musculoskeletal models used in such research require specific input parameters including anthropometric and strength characteristics which must be appropriate to the population being studied. Given the amount of resistance training typically undertaken by professional players and the position-specific demands of rugby, it is important to quantify these characteristics in place kickers to identify appropriate model inputs.

The aim of this study was to determine selected anthropometric and strength characteristics of rugby place kickers. We hypothesised that the mass and strength of professional place kickers would be greater than their amateur counterparts, and that the distribution of mass between segments within the body would also differ between these two groups. Where possible, selected variables were also compared to published values from healthy adult males and other sporting males to identify how the anthropometric and strength characteristics of rugby place kickers may differ from these populations.

METHODS: Following ethical approval, 35 rugby place kickers (Table 1) provided written informed consent to participate in this study which was part of a larger study of rugby place kicking technique. The kickers were grouped into professional and amateur players based on the level at which they played in the English Rugby Union structure. Professional players were all contracted to Premiership clubs and were currently playing in the Premiership or Championship (levels one and two), whilst the amateur players were predominantly playing at university-level and/or levels five to nine.

After a self-directed warm-up, all kickers completed a series of place kicks in to a net in a laboratory followed by four vertical jumps on a force platform (Kistler, 9287BA, 960 Hz). These jumps comprised two squat jumps (SJs) and two countermovement jumps (CMJs). The participants folded their arms across their chest for all jumps to reduce the effects of an arm swing on the outcome. After completion of the jumps, three photographs were taken of

each kicker standing within a planar six point calibration frame and wearing only a pair of shorts. One photograph was taken from a frontal view and one from each sagittal aspect.

Table 1
Age, mass and height of the two groups and comparable published data (mean \pm SD)

	Professional	Amateur	ES	Zatsiorsky & Seluyanov (1983) as used by de Leva (1996)	OpenSim (based on Anderson & Pandy, 1999)
n	16	19	-	100	5
Age (years)	19 \pm 1	24 \pm 4*	1.68	24 \pm 6	26 \pm 3
Mass (kg)	89.1 \pm 8.9	84.9 \pm 9.9	0.45	73.0 \pm 9.1	70.1 \pm 7.8
Height (m)	1.84 \pm 0.06	1.82 \pm 0.07	0.27	1.74 \pm 0.06	1.77 \pm 0.03

* significantly different ($p < 0.05$) from professional group. Effect sizes (ES) were calculated between the professional and amateur groups using Cohen's *d*.

Specific anatomical landmarks were digitised from the photographs using Motus (v.9, Vicon) and their coordinates (average of two independent digitisations) were reconstructed using 2D-DLT procedures. These coordinate data were used to follow the procedures of Gittoes et al. (2009) and yield input data for Yeadon's (1990) mathematical model. This provided inertia characteristics for 14 segments for each individual kicker from which specific masses, centre of mass locations and moments of inertia (Table 2) were extracted.

The vertical force data were exported and analysed in Matlab to obtain variables reflective of the strength characteristics of the kickers (Table 3). After low-pass filtering at 150 Hz, peak propulsive force was identified and jump heights were calculated from flight times using a 10 N threshold. Reactive strength index-modified (RSImod) was calculated for the CMJ using the procedures of Ebben and Petushek (2010). Values from the highest jump for each jump type were used for all subsequent analyses.

Values for each strength and inertia variable for each kicker were identified and the mean and standard deviation were calculated for the professional and amateur groups. Differences between the groups were assessed using an independent samples t-test with significance accepted below a *p* value of 0.05. Cohen's *d* was calculated as a measure of effect size for comparisons between the two groups of kickers, and effects were interpreted as small (0.2), medium (0.5) and large (0.8).

The mean data obtained from the groups of kickers were also compared with relevant previously published data. For the segmental inertia characteristics, the data commonly used in sports biomechanics research from Zatsiorsky and Seluyanov (1983) and de Leva (1996), as well as the data included in freely-available musculoskeletal modelling software (OpenSim, based on Anderson & Pandy, 1999) were used for comparison. For the strength characteristics, data from studies which reported comparable variables from the SJs and CMJs of athletes and physically-active adults where an arm swing was prohibited (Harman et al., 1990; Suchomel et al., 2015; 2016) were used for comparison.

RESULTS AND DISCUSSION: There was no significant difference in mass or height between the professional and amateur groups but there was a significant difference in their age (Table 1), predominantly due to the sample of professional kickers to which access was possible. Both groups of kickers were heavier and taller than the participants studied by Zatsiorsky and Seluyanov (1983) and Anderson and Pandy (1999).

For the inertia characteristics, our hypothesis was mainly rejected as the torso sagittal moment of inertia was the only head, torso, thigh or shank characteristic to differ between the two groups. Interestingly, although it could be expected among amateurs, the variation in anthropometric characteristics within the professional group (SD data in Table 2) suggests that there does not appear to be a high degree of similarity in anthropometry within professional rugby place kickers. Rather, these characteristics appear to be individual-specific and this has clear implications when input parameters are required for musculoskeletal models. In comparison to previously published data, the kickers' distribution of mass between the torso and thigh segment differed considerably from the mean data of de

Leva (1996), and slightly from the data used in OpenSim based on the model of Anderson and Pandy (1999). The moments of inertia also differed between the currently studied kickers and these previously studied participants, particularly for the torso segment (Table 2). This is likely due to the distribution of upper body musculature caused by the training specificity of rugby players and, given the relative mass of the torso segment, this also has potential implications for the accuracy of musculoskeletal models.

Table 2
Selected anthropometric characteristics of the two groups and comparable published data (mean ± SD)

	Professional	Amateur	ES	de Leva (1996)	OpenSim
Head mass as % of total	5.6 ± 0.4	5.7 ± 0.5	0.21	6.9	-
Torso mass as % of total	47.6 ± 1.6	47.0 ± 2.5	0.32	43.5	45.6
Thigh mass as % of total	12.3 ± 0.9	12.9 ± 1.2	0.56	14.2	12.4
Shank mass as % of total	4.7 ± 0.4	4.6 ± 0.3	0.11	4.3	4.9
Torso mass centre location (%)	52.4 ± 0.8	52.6 ± 0.9	0.27	51.4	-
Thigh mass centre location (%)	42.4 ± 0.7	42.2 ± 0.7	0.37	41.0	-
Shank mass centre location (%)	43.1 ± 0.7	43.0 ± 0.7	0.22	44.0	-
Torso sagittal Mol (kg·m ²)	1.463 ± 0.253	1.266 ± 0.265*	0.76	1.256	1.475
Torso frontal Mol (kg·m ²)	1.736 ± 0.290	1.532 ± 0.318	0.67	1.093	1.431
Torso transverse Mol (kg·m ²)	0.547 ± 0.085	0.524 ± 0.118	0.22	0.333	0.756
Thigh sagittal Mol (kg·m ²)	0.168 ± 0.035	0.185 ± 0.043	0.45	0.199	0.134
Shank sagittal Mol (kg·m ²)	0.048 ± 0.012	0.044 ± 0.009	0.37	0.038	0.050

* significantly different ($p < 0.05$) from professional group. Effect sizes (ES) were calculated between the professional and amateur groups using Cohen's d . Centre of mass locations are expressed relative to the proximal end of the segment. Mol = moment of inertia. The de Leva (1996) values are from the 100 males (mean ± SD: age = 24 ± 6 years, height = 1.74 ± 0.06 m, mass = 73.0 ± 9.1 kg) originally studied by Zatsiorsky and Seluyanov (1983). OpenSim values are adapted from the original model of Anderson and Pandy (1999) which is based on five adult males (mean ± SD: age = 26 ± 3 years, height = 1.77 ± 0.03 m, mass = 70.1 ± 7.8 kg).

Table 3
Selected strength characteristics of the two groups (mean ± SD)

	Professional	Amateur	ES
Squat jump height (m)	0.41 ± 0.04	0.35 ± 0.05*	1.14
Squat jump peak vertical force (BW)	2.30 ± 0.24	2.17 ± 0.18	0.63
Countermovement jump height (m)	0.44 ± 0.05	0.37 ± 0.06*	1.26
Countermovement jump peak vertical force (BW)	2.41 ± 0.19	2.33 ± 0.21	0.37
Countermovement jump RSI _{mod}	0.54 ± 0.10	0.43 ± 0.09*	1.16

* significantly different ($p < 0.05$) from professional group. Effect sizes (ES) were calculated between the professional and amateur groups using Cohen's d . RSI_{mod} = reactive strength index-modified.

For the strength characteristics, our hypothesis was accepted as the professional kickers jumped significantly higher than the amateur kickers (Table 3). These were large effects and corresponded to differences of 17% and 19% in SJ and CMJ height, respectively. When compared with previously published data from 21 male NCAA Division 1 soccer players, both the professional and amateur kickers jumped higher than the soccer players in the SJ (0.29 ± 0.04 m) and CMJ (0.34 ± 0.05 m; Suchomel et al., 2016). The RSI_{mod} values of the professional kickers from the CMJ were 26% higher than the amateur kickers, reflecting their greater ability to utilise the stretch-shortening cycle (Suchomel et al., 2016). Male NCAA Division 1 soccer players were previously found to exhibit RSI_{mod} values of 0.44 ± 0.09 m (Suchomel et al., 2015), similar to the amateur kickers yet less than the professional kickers. Although comparable strength characteristics of the participants studied by de Leva (1996) and Anderson and Pandy (1999) are not available, Harman et al. (1990) previously reported the peak vertical forces of 18 physically-active males (age = 29 ± 7 years, height = 1.79 ± 0.05 m, mass = 74.7 ± 7.7 kg) for a no-arm-swing SJ (2.13 ± 0.30 BW) and CMJ (2.32 ± 0.42 BW). The strength characteristics of place kickers, particularly professionals, should be considered when scaling the strength properties of such musculoskeletal models given these apparent differences and the importance of the muscle model parameters for the prediction of muscle forces. Further objective comparison of the strength characteristics of rugby

players against the strength characteristics of populations similar to those of the cadavers who were used in the development these musculoskeletal models is required.

CONCLUSION: Although there was little difference in the segmental inertia parameters between the professional and amateur kickers, differences were observed compared with data from other populations which are widely applied to performers from a variety of sports. Differences were most evident for the torso segment and, given that this represents almost half of the total mass of the person, rugby kicker-specific segmental inertia data may be an important consideration for use in musculoskeletal models of rugby place kicking technique. The professional kickers exhibited greater strength characteristics than the amateur kickers and these also appeared to be greater than those of other sportsmen and the general physically active population. If musculoskeletal models of rugby place kicking are to be developed to understand the potential injury risks, muscle model parameters are required which more closely represent the strength characteristics of this specific population.

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Acknowledgements

The authors are grateful to Mr Jack Lineham for his assistance during the experimental data collections and Dr Marianne Gittoes for her assistance during the segmental inertia data processing.