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Applied Musculoskeletal Assessment: Results from a Standardised Physical Assessment in a National Population of Professional Orchestral Musicians

Tim Driscoll[1]* and Bronwen Ackermann[2]

[1]Sydney School of Public Health, University of Sydney, Australia
[2]Discipline of Biomedical Science, University of Sydney, Australia

Abstract

Introduction: Australia has eight full-time professional symphonic and pit orchestras. This paper reports on the major findings from the physical examination component of a cross-sectional survey of the musicians, the first stage of a long-running national study and focuses on upper limb anthropomorphic measures and their association with different instrument types.

Methods: All musician members of the orchestras participating in this project were invited to undertake a physical assessment, using a standardized protocol. The overall response rate was 76% (n=408).

Results: The musicians were experienced (mean professional playing time = 20.6 years; standard deviation =10.7). For nearly all strength and anthropometric measures, men had higher mean results than women. Sex but not age was correlated with most measures. Many measures were highly correlated and most measures did not differ importantly between instruments. Upper strings players had significantly greater range of supination on the left but not the right; lower strings players had significantly greater hand span on the left but not the right; brass players had significantly greater grip strength and longer forearms.

Conclusion: This study provides detailed estimates for a large range of common anthropometric measures relevant to the physical assessment and musculoskeletal functioning of professional orchestral musicians and identified potentially important differences in some of these measures between musicians playing particular instruments.

Keywords: Musician; Musculoskeletal; Assessment

Introduction

Conducting a musculoskeletal assessment is a fundamental component of management of injuries [1]. Musculoskeletal assessments are now routinely used in elite sports and dance populations in an effort to identify musculoskeletal dysfunction that may predispose an individual to injury as well as increase understanding of the normal physical characteristics of these performers [2,3]. Normative musculoskeletal information obtained from assessment procedures is increasingly becoming available for particular athletic populations [4,5].

In the occupational group of professional orchestral musicians, musculoskeletal structures are reported to be the most commonly injured tissues, the damage occurring in response to exposure to a range of risk factors present in the workplace and associated with individual instruments [6,7]. Despite this, little is known about the musculoskeletal profile of these performers, creating challenges for the physical assessment of musicians and the implementation of effective injury management or prevention protocols.

Accordingly, a physical examination protocol [8] was conducted by a team of trained physiotherapists in eight large professional orchestras as part of a national orchestral occupational health project, Sound Practice. The musculoskeletal assessment procedures were selected to maximize reliability when performed by different raters [9] and the tests chosen to best reflect the specific needs of the orchestral musician. The aim of the study was to establish baseline measures for a range of mostly upper body musculoskeletal assessment procedures in professional musicians and to examine the extent of variation between instrumentalists that might result from the particular load created by the physical demands of many years of playing their instrument.

Methods

Participants

All musician members of the orchestras participating in this project were invited to participate in a physical examination conducted by a team of physiotherapists trained to conduct a standardized protocol of procedures. The response rate varied between 49% and 98% between the eight different orchestras and was 76% overall.

Musculoskeletal assessment protocol

The musculoskeletal assessment protocol and considerations in its design, have been described in detail previously [8]. The assessment aimed to cover the main parts of the body reported to be prone to sustaining musculoskeletal injuries in the musician population. The protocol was trialled with another orchestra not participating in this project and was subsequently modified and designed to be able to be completed within one hour, based on the trial results and experiences during training of the study physiotherapists. The assessment involved the team travelling to different venues to conduct

***Corresponding author:** Tim Driscoll, Associate Professor, Sydney School of Public Health, University of Sydney, Edward Ford Building, University of Sydney, Sydney, NSW, Australia, Tel: +61 2 9351 4372; Fax: +61 2 9351 5049; E-mail: tim.driscoll@sydney.edu.au

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testing, so the approach needed to be portable whilst maintaining reliability. Participating physiotherapists were recruited in a number of ways. Orchestras were asked to provide contact details of any physiotherapists working with the musicians who may have been willing to participate in this study. Secondly, hand therapists working with musicians and sports physiotherapists who were very experienced in conducting physical assessments in athletic populations were invited to participate. Eighteen physiotherapists, with an average clinical experience of 15 years, attended training and were involved in the assessments. The physiotherapists were trained at a single venue prior to the commencement, with on-going calibration undertaken on an ad-hoc basis during the testing period. An occupational physician also made some of the forearm and the majority of the hand measures. To evaluate reliability, inter-rater reliability tests were conducted initially and at several testing venues over the course of the trial [8].

Results were recorded directly to digital sound recorders or on paper, depending on the specific measurement being made. The sound-recorded data were later transferred to paper coding sheets and the data entered into a spreadsheet for analysis. Regression analyses were conducted to examine the relationship between the main measures and instrument type. All analyses were conducted using the Statistical Analysis System [10]. Differences between instruments were examined using broad instrument groups (with brass instruments as the baseline comparison group) and specific instruments (using the French horn as the baseline comparison group).

This study was approved by The University of Sydney Human Research Ethics Committee.

Results

Four hundred and eight musicians participated in the study. This was approximately 76% of the eligible musicians. The average age of the participating musicians was 42.1 years (standard deviation (s.d.) = 10.2), with most aged between 25 and 54 and a range of 18 to 68 years (Table 1). There were slightly more women (51%) than men and their age distribution was similar. The most common instrument group played by the musicians was upper strings (violin and viola – 45%), with most of the remainder fairly evenly spread between lower strings, woodwind and brass. The sex distribution varied across instrument type, with notably a much higher proportion of males playing brass and percussion/tympani and a much higher proportion of females playing upper strings, particularly the violin (Table 2). The players were experienced, with a mean time playing as a professional of 20.6 years (s.d. = 10.7); only 18% had played for less than 10 years.

For all strength measures, males had much higher mean results than females. Many of the other measures also differed considerably between males and females. Therefore, most results are presented separately by sex (Table 3, Table 4, Table 5 and Table 6). Many measures were highly correlated and most measures were not markedly different between different instrument groups and between specific instruments, although some were. These relationships were explored in detail using linear regression analysis. The measures were not correlated with age, so age was not included in the final regression models. Sex was highly correlated with most measures and was maintained in all models. Findings of particular interest are described here.

Age	Number[1]	%
15-24	7	1.9
25-29	49	13.1
30-34	45	12.0
35-39	53	14.1
40-40	59	15.7
45-49	70	18.7
50-50	45	12.0
55-59	31	8.3
60-69	16	4.3
Total	**375**	**100.0**

1: Age was missing for 33 musicians because they did not complete the questionnaire phase of the study

Table 1: Age of musicians (number, per cent).

Instrument	Males		Females		Total[1]	
	n	%	n	%	n	%
Upper strings						
Violin	43	21.6	84	40.8	127	31.4
Viola	21	10.6	34	16.5	55	13.6
Total	**64**	**31.2**	**118**	**47.3**	**182**	**44.9**
Lower strings						
Cello	25	12.6	23	11.2	48	11.9
Double Bass	17	8.5	9	4.4	26	6.4
Total	**42**	**21.1**	**32**	**15.6**	**74**	**18.3**
Woodwind						
Flute	6	3.0	16	7.8	22	5.4
Oboe	9	4.5	9	4.4	18	4.4
Bassoon	8	4.0	9	4.4	17	4.2
Clarinet	12	6.0	2	1.0	14	3.5
Total	**35**	**17.5**	**36**	**17.6**	**71**	**17.5**
Brass						
French horn	16	8.0	12	5.8	28	6.9
Trombone	16	8.0	1	0.5	17	4.2
Trumpet	11	5.5	1	0.5	12	3.0
Tuba	4	2.0	0	-	4	1.0
Total	**47**	**23.5**	**14**	**6.8**	**61**	**15.1**
Percussion and tympani						
Percussion	6	3.0	1	0.5	7	
Tympani	5	2.5	1	0.5	6	
Total	**11**	**5.5**	**2**	**1.0**	**13**	**3.2**
Other						
Harp	0	-	4	1.9	4	
Total			**4**	**1.9**	**4**	**1.0**
Total	**199**	**100.0**	**206**	**100.0**	**408**	**100.0**

1: Sex was missing for three musicians

Table 2: Instrument group and instrument played (number, per cent).

Left arm supination range of motion was significantly related to instrument group ($F_{4, 384}$=3.92, p<0.004), taking into account sex, with the upper strings group having the biggest range of motion. Exploring this in more depth using the individual instrument coding, left arm supination was highest in violin players, with an estimated 5.7 degrees (95% CI=0.51 to 11.0 degrees) more of supination compared to the baseline french horn players (t_{388}=2.16, p=0.032). There was no significant relationship between right arm supination and instrument group ($F_{4, 384}$=1.28, p=0.28).

Left hand grip strength was significantly related to instrument group ($F_{4, 390}$=2.18, p=0.019), taking into account sex, with the upper strings group and lower strings group having the lowest strength and

	Brass	Woodwind	Lower strings	Upper strings	Percussion/ tympani	All players		
Measurement	**n=47**	**n=35**	**n=42**	**n=64**	**n=11**	**n=199**	**Minimum**	**Maximum**
Shoulder external rotation – left[1]	12.3	11.5	12.6	12.1	12.1	12.1	6.4	24.2
	2.5	2.2	3.3	2.5	2.4	2.6		
Shoulder external rotation - right[1]	12.5	11.8	13.1	12.1	12.5	12.4	7.3	27.8
	2.5	2.2	3.4	2.2	2.0	2.6		
Shoulder internal rotation - left[1]	16.8	16.2	16.0	15.0	15.7	15.9	5.5	27.4
	3.7	4.3	3.7	4.5	3.3	4.1		
Shoulder internal rotation - right	17.5	16.1	16.0	16.2	16.9	16.5	5.0	30.7
	4.3	4.3	3.8	4.4	3.1	4.2		
Shoulder abduction - left[1]	18.7	18.2	18.9	17.5	19.4	18.3	7.3	33.0
	4.9	4.3	5.1	4.5	3.7	4.7		
Shoulder abduction - right[1]	19.8	19.3	19.7	18.6	20.0	19.3	8.0	32.7
	4.6	4.9	5.2	4.4	3.4	4.6		
Shoulder - HK – left[2]	39.3	45.3	45.0	41.9	45.1	42.7	8.0	89.0
	11.2	14.0	14.2	13.8	12.3	13.4		
Shoulder - HK – right[2]	37.0	40.2	38.2	38.3	44.4	38.7	10.0	90.0
	12.8	11.1	14.2	11.6	11.5	12.4		
Kiblers - A – left[3]	10.4	10.6	10.1	10.2	10.0	10.3	6.0	15.0
	1.6	1.4	1.7	1.5	2.0	1.6		
Kiblers - A – right[3]	11.0	10.8	10.4	10.7	11.1	10.7	6.5	16.0
	1.7	1.6	1.8	1.6	2.1	1.7		
Hand behind back – left[4]	27.4	25.9	26.8	26.6	29.1	26.9	2.0	45.5
	7.0	6.6	5.3	6.8	4.5	6.4		
Hand behind back – right[4]	29.9	28.1	29.0	28.2	30.5	28.9	4.0	58.0
	6.8	6.5	5.8	7.6	4.6	6.7		
Hand behind head – left[5]	13.0	12.3	14.0	12.0	13.0	12.8	0.0	32.0
	3.2	3.9	4.1	3.6	2.6	3.7		
Hand behind head – right[5]	12.5	11.9	13.1	13.0	13.3	12.7	4.5	32.0
	3.2	3.5	4.2	2.9	3.1	3.4		

1: Strength (measured in Newtons)
2: Hawkins-Kennedy test of extent of internal rotation of the shoulder measured at 90 degrees of shoulder flexion (measured in degrees)
3: Kibler's lateral slide test, assessing distance between the inferior angle of the scapula and the spinous process of T7 (measured in cm)
4: The subject was instructed to put their hand behind their back and reach up as far as they could. The measure is the distance between tip of middle finger and the spinous process of T1 – a shorter distance shows better range of movement (measured in cm)
5: The subject was instructed to put their hand behind their head and reach down as far as they could. The measure is the distance between tip of middle finger and the spinous process of T1 – a larger distance shows better range of movement (measured in cm)

Table 3: Shoulder strength and range of motion measurements – by instrument type – males - (mean and standard deviation).

the brass players the highest strength. The analysis of right hand grip strength showed similar findings ($F_{4, 390}$=2.01, p=0.09), except that the differences were smaller.

Forearm length differed between instrument group on the left ($F_{4, 376}$=3.90, p=0.004) and the right ($F_{4, 376}$=3.28, p=0.011), with brass players having the longest forearms and woodwind and upper strings players (and tympani on the left) the shortest forearms of the major instrument group players. Also, the left hand span ($F_{4, 391}$=3.30, p=0.011), but not the right hand span ($F_{4, 389}$=0.54, p=0.71), differed between instrument groups, taking into account sex, with lower strings players having the largest hand span and upper strings and woodwind players the smallest.

Using a cut-off of five or more out of nine as an indicator, 8.2% (28/342) of participants met the criteria for possible joint laxity and hyper mobility syndrome (66 participants had at least one of the nine test missing and so could not be included in the joint laxity assessment). There was no significant difference between these proportions in males and females, nor any apparent relationship with instrument group.

Discussion

The results from this musculoskeletal assessment of a large group of professional orchestral musician's gives normative data against which results in a physical examination setting can be compared. Furthermore, the results clearly show differences in musculoskeletal profiles of certain instrumental groups. This probably reflects several factors.

Measurement	Brass n=14	Woodwind n=36	Lower strings n=32	Upper strings n=118	n=206[1]	All players Minimum	Maximum
Shoulder external rotation – left[2]	9.1	8.6	8.8	8.3	8.5	3.8	17.4
	2.5	2.4	1.7	1.8	2.0		
Shoulder external rotation - right[2]	9.0	8.4	9.0	8.4	8.5	3.3	18.1
	1.0	2.0	1.8	1.8	1.8		
Shoulder internal rotation - left[2]	11.7	11.2	10.9	10.5	10.7	3.7	20.5
	1.4	3.1	2.1	2.7	2.6		
Shoulder internal rotation - right[2]	11.2	11.0	11.3	11.0	11.0	3.1	23.0
	2.0	3.1	2.6	3.1	3.0		
Shoulder abduction - left[2]	13.4	12.5	12.7	12.8	12.7	4.2	24.0
	3.6	3.6	2.8	3.7	3.5		
Shoulder abduction - right[2]	13.6	12.8	13.4	13.3	13.2	3.9	22.7
	3.1	3.7	2.8	3.5	3.4		
Shoulder - HK – left[3]	43.9	41.4	40.4	40.1	40.5	5.0	90.0
	12.4	13.1	10.7	13.7	13.0		
Shoulder - HK – right[3]	37.7	34.1	37.5	35.5	35.5	1.0	68.0
	11.0	10.5	10.4	11.4	11.2		
Kiblers - A – left[4]	9.0	8.6	8.7	8.4	8.5	5.0	14.0
	1.7	1.4	1.3	1.6	1.5		
Kiblers - A – right[4]	9.1	9.0	8.9	8.8	8.8	5.0	16.5
	1.5	1.6	1.3	1.5	1.5		
Hand behind back – left[5]	24.4	22.8	23.6	22.6	23.0	0	41.0
	4.9	4.2	4.5	5.9	5.3		
Hand behind back – right[5]	26.3	25.6	25.7	24.2	25.1	2.5	50.0
	6.1	4.8	6.1	6.2	6.2		
Hand behind head – left[6]	9.9	11.1	10.0	11.0	10.7	4.0	19.0
	2.7	2.5	2.3	2.5	2.5		
Hand behind head – right[6]	10.6	10.6	10.6	11.2	10.9	0	17.0
	2.7	2.8	2.8	2.7	2.7		

1: Includes two percussionists and four harp players.
2: Strength (measured in Newtons).
3: Hawkins-Kennedy test of extent of internal rotation of the shoulder measured at 90 degrees of shoulder flexion (measured in degrees).
4: Kibler's lateral slide test, assessing distance between the inferior angle of the scapula and the spinous process of T7 (measured in cm).
5: The subject was instructed to put their hand behind their back and reach up as far as they could. The measure is the distance between tip of middle finger and the spinous process of T1 – a shorter distance shows better range of movement (measured in cm).
6: The subject was instructed to put their hand behind their head and reach down as far as they could. The measure is the distance between tip of middle finger and the spinous process of T1 – a larger distance shows better range of movement (measured in cm).

Table 4: Shoulder strength and range of motion measurements – by instrument type – females - (mean and standard deviation).

One important factor is likely to be a selection issue, where anthropomorphic characteristics favor a musician being selected into a particular instrument group, or allowing a musicians to perform at a sufficiently expert level to allow them to play professionally. For example, brass players are probably favored by having longer and stronger forearms and hands, as found in this study. Also, lower strings players require large reach in the left hand but not their right (bow) hand and in this study were found to have a larger hand span on the left but not the right.

The second factor is the potential impact that many years of very specific physical skills may have on anthropomorphic characteristics. The finding of a greater hand span on the left than the right in lower strings players could, as just suggested, reflect selection pressures where persons with big left hands, regardless of right hand size, would be more adept at playing the lower strings instruments. However, the finding is probably more suggestive that the two hands were originally the same size and that, after years of playing, the elite cello and double bass players have in fact increased their hand span on the left through stretching of joint ligaments, muscles and tendons. Similar explanations probably underpin the finding of a greater range of supination (but not pronation) in the left forearm (but not right forearm) of upper strings players, particularly violinists. These players require marked supination at the end of range in the left forearm to enable them to achieve the best fingering on the neck of the instrument. It is likely that years of playing have extended the range of left forearm supination, showing the physical effect of the left arm action required to achieve mastery on the upper strings instruments, but there may have been some contribution from innate personal factors allowing the player to achieve that extent of supination.

With the high number of measurements made and thus the potential for multiple comparisons producing spurious findings of "statistical significance", the findings from this study need to be interpreted in the light of the anatomical and physiological requirements of playing particular instruments. Not all "statistically significant" differences signal a real and important difference between musicians. The findings considered in detail in this paper are those where the anthropometry is consistent with the known or suspected demands of playing particular instruments and as such are more likely to reflect real anthropometric differences between musicians.

As has been noted previously, there has been a lack of gold standards for many musculoskeletal measurements relevant to musicians [11,12]. The results presented in Table 3, Table 4, Table 5 and Table 6 provide detailed reference measurements for use as normative data in the professional musician population. Many of the measurements did not

	Brass	Woodwind	Lower strings	Upper strings	Percussion/ tympani	All players		
Measurement	**N=47**	**n=35**	**n=42**	**n=64**	**n=11**	**n=199**	**Minimum**	**Maximum**
Elbow - pronation – left[1]	78.2	85.1	84.4	78.5	87.0	81.3	51.0	110.0
	9.5	9.3	10.9	10.9	8.8	10.6		
Elbow - pronation - right[1]	80.3	82.5	84.3	80.8	85.5	82.0	44.0	118.0
	10.6	10.0	9.8	11.2	14.5	10.8		
Elbow - supination - left[1]	87.7	89.8	93.9	97.0	86.9	92.3	60.0	165.0
	10.7	10.7	9.0	15.5	12.4	12.8		
Elbow - supination - right[1]	85.6	90.7	89.7	88.3	94.5	88.7	9.2	140.0
	12.2	10.7	18.8	13.2	11.5	14.0		
Elbow flexion – left[2]	24.5	23.7	24.2	23.0	25.6	23.9	9.1	46.2
	5.5	3.5	5.1	5.5	5.3	5.1		
Elbow flexion - right[2]	25.4	24.2	25.0	23.9	25.9	24.7	9.7	45.2
	5.3	4.5	4.9	5.5	3.9	5.0		
Elbow extension - left[2]	19.7	19.4	18.9	18.0	18.8	18.9	8.9	32.0
	4.1	3.3	4.3	4.6	4.8	4.2		
Elbow extension - right[2]	19.8	19.3	19.0	18.4	18.6	19.1	8.7	33.0
	4.0	4.3	4.0	4.4	4.3	4.2		
Wrist flexion - left[2]	17.0	17.0	18.0	16.5	17.5	17.1	5.8	35.3
	4.2	4.7	5.1	4.7	3.8	4.6		
Wrist flexion - right[2]	18.1	18.1	18.6	17.4	19.5	18.1	4.8	38.5
	4.2	5.2	5.1	5.0	3.7	4.8		
Wrist extension - left[2]	16.7	16.0	16.2	15.7	16.2	16.1	8.1	28.2
	3.7	3.2	4.1	3.9	3.1	3.7		
Wrist extension - right[2]	17.5	16.4	17.4	16.3	16.3	16.8	8.5	30.7
	3.6	3.5	4.2	3.9	2.6	3.8		
Hand grip - left[2]	44.4	42.6	42.2	40.1	42.8	42.2	15.0	64.5
	7.3	8.9	8.8	10.1	4.9	8.8		
Hand grip - right[2]	46.4	45.1	45.2	43.3	45.7	44.9	18.0	72.0
	7.9	9.4	9.1	9.6	4.5	8.9		
Hand - pinch grip - left[2]	4.8	5.5	5.3	4.7	5.2	5.0	0.8	13.9
	2.5	3.2	2.7	2.4	2.3	2.6		
Hand - pinch grip - right[2]	5.3	5.9	5.4	5.0	5.4	5.3	1.3	15.4
	2.3	2.6	2.4	2.5	1.6	2.4		
Hand - thumb abduction - left[2]	3.7	3.8	3.9	3.5	3.3	3.7	1.5	6.7
	0.8	1.0	1.1	0.9	0.9	0.9		
Hand - thumb abduction - right[2]	3.9	4.1	4.0	3.5	3.1	3.8	1.3	7.0
	1.0	1.0	1.1	1.0	0.8	1.0		
Hand - thumb extension - left[2]	2.6	2.7	2.6	2.6	2.6	2.6	1.0	5.8
	1.0	1.2	1.0	0.9	1.2	1.0		
Hand - thumb extension - right[2]	2.7	3.0	2.8	2.7	2.7	2.8	0.8	6.1
	1.1	1.3	1.0	0.9	1.0	1.0		
Upper arm length – left[3]	33.9	33.8	34.1	33.3	33.7	33.7	28.0	38.4
	1.8	1.9	1.9	2.1	1.7	2.0		
Upper arm length - right[3]	33.8	33.7	34.1	33.4	33.5	33.7	28.0	39.0
	2.0	2.0	1.7	2.2	2.6	2.0		
Forearm length - left[3]	27.9	27.5	28.0	27.3	27.2	27.6	23.0	32.4
	1.3	1.6	1.6	1.9	2.0	1.7		
Forearm length - right[3]	27.9	27.4	28.1	27.2	27.8	27.6	23.0	33.0
	1.4	1.6	1.7	1.7	2.6	1.7		
Hand span - left[3]	22.9	22.4	23.2	22.4	22.8	22.7	19.2	26.5
	1.1	1.5	1.5	1.4	1.2	1.4		
Hand span - right[3]	22.3	22.3	22.4	22.0	22.5	22.2	19.1	25.7
	1.2	1.4	1.6	1.4	1.2	1.4		

1: Range of motion (measured in degrees).
2: Strength (measured in Newtons).
3: Measured in centimetres.

Table 5: Elbow, forearm and hand anthropometric, strength and range of motion measurements – by instrument type – males - (mean and standard deviation).

	Brass	Woodwind	Lower strings	Upper strings		All players	
Measurement	**n=14**	**n=36**	**n=32**	**n=118**	**n=206[1]**	**Minimum**	**Maximum**
Elbow - pronation – left[2]	78.6	82.9	82.6	82.6	82.3	50.0	109.0
	12.3	8.8	10.9	11.8	11.1		
Elbow - pronation - right[2]	82.9	81.9	81.0	83.2	82.6	50.0	110.0
	11.2	10.1	10.0	11.4	11.0		
Elbow - supination - left[2]	99.3	98.1	96.4	100.0	99.0	60.0	162.0
	10.0	15.6	9.4	13.2	12.9		
Elbow - supination - right[2]	92.1	94.3	93.4	93.6	93.5	63.0	145.0
	10.8	11.1	11.7	11.5	11.2		
Elbow flexion – left[3]	17.7	15.8	16.0	15.5	15.7	4.6	22.3
	2.0	3.4	2.2	3.5	3.2		
Elbow flexion - right[3]	18.2	16.1	16.4	16.2	16.2	4.1	27.4
	2.4	3.5	3.7	3.4	3.5		
Elbow extension - left[3]	12.9	12.8	13.0	12.6	12.7	4.2	22.4
	2.2	3.3	2.9	3.1	3.0		
Elbow extension - right[3]	13.3	12.9	13.5	13.0	13.0	3.7	27.0
	2.3	3.0	3.0	3.5	3.2		
Wrist flexion - left[3]	11.5	10.2	10.3	10.9	10.7	4.2	20.9
	3.3	2.7	2.7	3.2	3.0		
Wrist flexion - right[3]	13.2	11.3	11.0	11.5	11.5	3.3	24.2
	3.2	3.4	2.9	3.4	3.3		
Wrist extension - left[3]	10.8	10.1	10.8	10.6	10.6	5.5	24.2
	1.2	2.3	3.0	2.7	2.6		
Wrist extension - right[3]	11.4	10.7	11.5	10.8	10.9	4.6	24.9
	1.6	2.7	3.6	2.6	2.8		
Hand grip - left[3]	29.6	27.9	26.2	26.2	26.7	10.0	42.0
	4.5	5.1	5.5	5.8	5.5		
Hand grip - right[3]	31.5	29.7	27.7	27.8	28.3	5.0	43.0
	5.7	5.2	5.8	6.2	5.9		
Hand - pinch grip - left[3]	3.1	3.7	2.9	3.5	3.4	0.5	10.0
	1.7	2.0	1.5	1.9	1.9		
Hand - pinch grip - right[3]	3.9	4.2	3.2	3.9	3.9	0.8	12.0
	2.0	2.0	1.4	2.2	2.0		
Hand - thumb abduction - left[3]	2.6	2.7	2.6	2.7	2.6	1.3	7.2
	0.7	0.9	0.6	0.8	0.8		
Hand - thumb abduction - right[3]	2.8	2.9	2.6	2.7	2.7	0.9	8.4
	0.7	0.9	0.6	0.9	0.9		
Hand - thumb extension - left[3]	1.5	1.7	1.9	1.8	1.8	0.4	4.9
	0.7	0.9	0.8	0.7	0.8		
Hand - thumb extension - right[3]	1.7	1.9	1.8	1.8	1.8	0.4	5.4
	0.9	1.0	0.6	0.7	0.8		
Upper arm length – left[3]	32.7	31.1	31.4	31.1	31.3	25.5	37.0
	1.7	1.9	1.4	2.1	2.0		
Upper arm length - right[3]	32.5	30.9	31.1	31.2	31.2	26.0	37.0
	1.4	1.7	1.3	2.0	1.9		
Forearm length - left[3]	26.6	24.6	25.1	24.7	24.9	20.0	31.0
	1.5	1.7	1.8	1.6	1.7		
Forearm length - right[3]	26.2	24.8	24.7	24.7	24.8	21.0	29.5
	1.2	1.5	1.2	1.5	1.5		
Hand span - left[3]	20.4	20.1	20.8	20.5	20.5	16.5	28.5
	1.3	1.1	1.2	1.5	1.4		
Hand span - right[3]	19.5	19.8	20.2	20.1	20.0	16.2	28.2
	1.5	1.2	1.3	1.5	1.4		

1: Includes two percussionists and four harp players.
2: Range of motion (measured in degrees).
3: Strength (measured in Newtons).

Table 6: Elbow, forearm and hand anthropometric, strength and range of motion measurements – by instrument type – females - (mean and standard deviation).

appear to differ in importance between different types of musicians. As expected, there were clear differences in many measurements between males and females, but not between different age groups.

About one quarter of eligible musicians did not participate in the aspect of the study reported here. This raises the possibility of selection bias influencing the relationships identified in the study. There is no reason to think that the musicians who did not participate would have differed importantly in terms of their baseline anthropometry, including the specific relationships seen in musicians playing upper strings, the lower strings and the brass instruments. Information that was available regarding musicians who did not participate did not suggest that the reasons for not participating was related to anatomical or physical functioning, but rather that they were concerned about anonymity or that they perceived they were not encouraged to participate by more senior musicians or by management.

All the measures used have imperfect sensitivity and specificity. The measures were chosen as much as possible to include only measures with known and acceptable, sensitivity and specificity. Some variation between the 18 testers would also be expected. Indeed, assessments of reliability during the study showed such variation, but also that in general the variation was not clinically important [8]. Nevertheless, what error that was present is very unlikely to be related to the specific type of musician. Instrument type was commonly not known at the time of measurement, although testers were not formally blinded to the instrument played and the instrument type was not uncommonly known by the end of the measurement session as a result of discussion between musician and tester. Any measurement error arising in these circumstances would be expected to blur any true differences between musician types and thus would make true differences harder to identify, rather than to have produced the relationships seen between instrument type and specific anatomical feature (such as greater range of supination in the left arm of upper strings players).

This study has produced estimates of mean and standard deviation for a large range of common anthropometric measures relevant to the physical assessment and musculoskeletal functioning of professional orchestral musicians in Australia. It has also identified potentially important differences in some of these measures between musicians playing particular instruments. These findings should be relevant to professional orchestral musicians in most orchestras around the world. The information presented here should be useful as a baseline for future assessments of musicians and also as an indication of the kind of musculoskeletal characteristics a player may need to achieve before returning to performance. The questionnaire phase of the study suggests that many musicians do not make fast or complete recovery from musculoskeletal problems (unpublished results) and the information provided by this study may assist the development of realistic and appropriate rehabilitation goal-setting processes. It also helps to improve understanding of the selection pressures that propel musicians with particular anatomical features to successfully play particular instruments (and presumably hinder other musicians without these features being successful with that type of instrument) and the functional anatomical effects of the extremes of movements required to play certain instruments at the elite level.

Key Messages

The study provides anthropomorphic estimates for a large range of common anthropometric measures relevant to the physical assessment and musculoskeletal functioning of professional orchestral musicians.

Each instrument places specific physical demands on the musician and may modify the functional anatomy of the musician to better meet the demands of playing that instrument.

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