Anthropometric Data of Chilean Male Workers

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Abstract. The aim of this study was to update the Chilean male workers' anthropometric database to be used for design purposes and to examine the secular changes observed in a group of anthropometric variables for Chilean male workers. Data collection involved a sample of 2,346 male workers with ages ranging from 18 to 65+, assigned to the Mutual de Seguridad C.Ch.C in the two most populated regions of Chile (Valparaíso and Metropolitana) distributed in nine economic activities branches. Data collection was performed by two teams of 3 physiotherapies each. Before starting the collection process, the measurement teams underwent a training session of one week that included a theoretical session on the basic concepts of anthropometrics, as well as some practical instructions. A total of 32 anthropometric measures were gathered following the ISO standard 7250-1. Before applying the data, a checking process was carried out, trying to identify errors related to the data collection process. The magnitude of the positive secular trend for the stature was 1.0 cm per decade and the highest value was found for shoulder breadth, with a positive increase of 2.7 cm per decade. The results obtained allowed to observe the existence of a positive secular trend for most of the selected body measurements. Finally, it was also possible to verify that the current research may be used for design purposes and to establish the baseline data for long-term observation regarding anthropometric changes among Chilean male workers.

1 Introduction

Anthropometry is concerned with body measurements of people, with the aim of achieving comfort, optimal fit and usability [1]. Anthropometric data of populations is a key input to produce high levels of physical accommodation. All products for the final

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user, as well as products for work systems, need to be adjusted to the anthropometric characteristics of people that will be using them on a regular basis.

Our first and only database was created nearly two decades ago [2]. The use of these data could make designs inadequate, mainly if one considers that the data can be outdated, in particular due to the existence of secular trend. The secular trend is the growth observed over long periods of time on a specific population. It has been defined as an increase in the average stature between people of the same age along successive generations [3]. This positive secular trend has been observed in different countries, with an average growth in stature between 0.7 cm and 4.0 cm per decade [4, 5]. Positive secular trends have been observed in several countries [6–9]. Furthermore, this positive secular trend can stop after a period of continuous growing, such was the case for the Dutch population, which stopped growing taller after a period of almost 150 years [10]. Secular trend is caused by changes in environmental conditions, both favoring or hindering the full expression of biological (genetic) potential, such as infectious diseases, nutrition, poverty and suffering [11]. A positive secular trend is also assumed to reflect changes in living standards and dietary habits [12].

Increasing prevalence of musculoskeletal problems in working populations has been a concern in developed and developing countries [13–15]. If a product has a low level of match with a particular end-user population, there could be an increase on biomechanical stress of joints and muscles, thus contributing to a relevant extent to the occurrence of musculoskeletal disorders [16, 17].

The use of incorrect anthropometric dimensions and the failure to consider the changes resulting from secular trends threatens the sustainability of products and spaces over time, since in the face of possible problems, they will have to be modified, with the costs involved once they have been manufactured [18].

The main objective of the following work was to document and update the anthropometric database for Chilean male workers. A second objective was to determine the presence of a secular trend among Chilean male workers.

2 Methods

2.1 Sample

A representative group of male workers, with ages ranging from 18 to 65+, assigned to the Mutual de Seguridad C.Ch.C (hereinafter called workers) in the 2 most populated regions of Chile (Valparaíso and Metropolitana) distributed in 9 branches of economic activity (Agriculture and Fishing, Mining, Manufacturing, Electricity, Construction, Commerce, Transport and Communications, Financial Services, and Communal and Personal Services) was used. For each region, a stratified sampling plan was carried out by economic activity, by means of clusters. For this investigation, a cluster corresponds to a group of 20 workers. To calculate the number of clusters in the sample, $p = 0.5$ was selected, which corresponds to the proportion of workers who have anthropometric measures outside the usual ranges. This proportion gives the maximum sample size or number of clusters to be selected from the population in each region. The estimated error was set at 0.04. To determine the number of clusters in the sample for each of the regions, the data on the number of average monthly workers and the weighting by economic activity were used. The estimated sample of workers for the region of Valparaiso was fixed at 760 and for the Metropolitan region at 1,320. Finally, considering the gender distribution in Mutual de Seguridad C.Ch.C the final sample estimated was 1,493 male workers.

2.2 Data Collection

In order to define a large number of dimensions for different design purposes, the following anthropometric measures were considered [19], and are described below:

- Weight: total mass (weight) of the body.
- Stature: vertical distance between the floor and the top of the head, measured with the subject erect and looking straight ahead (Frankfurt plane).
- Body mass index (unit): calculated through Weight (kg)/Stature (m2).
- Eye height: calculated through (Stature – (Sitting height – Eye height sitting)).
- Shoulder height: calculated through (Stature – (Sitting height – Shoulder height sitting)).
- Elbow height: calculated through (Stature – (Sitting height – Elbow height sitting)).
- Knuckle height: vertical distance from the floor to metacarpal III (i.e. the knuckle of the middle finger).
- Sitting height: vertical distance between subject's seated surface to the top of the head, measured with the subject erect and looking straight ahead (Frankfort plane).
- Eye height sitting: vertical distance between the sitting surface to the inner canthus (corner) of the eye (head in Frankfurt plane).
- Shoulder height sitting: vertical distance from subject's seated surface to the acromion.
- Subscapular height: vertical distance from the lowest point (inferior angle) of the scapula to the subject's seated surface.
- Grip reach. Forward reach: horizontal distance from a vertical surface to the grip axis of the hand while the subject leans both shoulder blades against the vertical surface.
- Elbow grip length: horizontal distance from back of the upper arm (at the elbow) to grip axis, with elbow bent at right angles.
- Shoulder-elbow length: calculated through (Shoulder height sitting – Elbow height sitting).
- Elbow height sitting: taken with a 90° angle elbow flexion, as the vertical distance from the bottom of the tip of the elbow (olecranon) to the subject's seated surface.
- Abdominal depth: maximum horizontal distance from the vertical reference plane to the front of the abdomen in the standard sitting position.
- Thigh Clearance: vertical distance from the highest uncompressed point of thigh to the subject's seated surface.
- Buttock-Popliteal Length: horizontal distance from the popliteal surface to the rearmost point of the buttock.
- Buttock-knee length: horizontal distance from the foremost point of the knee-cap to the rearmost point of the buttock.

- Knee height: vertical distance from the floor or footrest to the highest point of the superior border of the patella.
- Popliteal height: vertical distance from the floor or footrest to the posterior surface of the knee (popliteal surface).
- Shoulder (bideltoid) breadth: distance across the maximum lateral protrusions of the right and left deltoid muscles.
- Elbow to elbow breadth: maximum horizontal breadth across the elbows.
- Hip breadth: horizontal distance measured in the widest point of the hip in the sitting position
- Hand length: perpendicular distance from a line drawn between the styloid processes to the tip of the middle finger.
- Hand Breadth (across thumb): projected distance between radial and ulnar at the level of the metacarpal-phalangeal joint of digit 1 to the ulnar side of the hand. second to the fifth metacarpal.
- Hand Breadth (metacarpal): projected distance between radial and ulnar metacarpals at the level of the metacarpal heads from the second to the fifth metacarpal.
- Foot breadth: maximum distance between medial and lateral surfaces of the foot perpendicular to the longitudinal axis of the foot.
- Foot length: maximum distance from rear of the heel to tip of the longest (first or second) toe, measured parallel to the longitudinal axis of the foot.
- Head circumference: maximum, approximately horizontal, circumference of head measured above the glabella and crossing the rearmost point of the skull.
- Neck circumference: circumference of neck at a point just below the bulge at the thyroid cartilage.
- Waist circumference: circumference of trunk at a level midway between the lowest ribs and the upper iliac crest.

The measurement process was carried out by a team of six physiotherapists, divided in two teams. Before starting the survey, the measurement teams underwent a one-week training session, including a theoretical approach to anthropometrics, as well as practical instructions lectures. They spent a considerable amount of time practicing the measurements in order to achieve high consistency between measurers. At the end of the training session, a pilot study was developed with a sample of 25 volunteers that were measured twice by the two teams and both inter- and intra-measurer reliability were assessed using the Intraclass Correlation Coefficient (ICC) model's "two-way mixed" and "absolute agreement" types. Correlations were interpreted according to the ranges suggested by Portney and Watkins [20], namely an ICC $\geq$ 0.50 was interpreted as being moderate and an ICC $\geq$ 0.75 was interpreted as being strong. The results show that measurers have a strong value of inter- and intra-reliability.

Finally, quality data process was done through different steps, namely: observation of mean, minimum, and maximum values, calculation of the different measurements, observation of scatter plot graphics (Stature and Weight with the other variables) and percentiles' profile.

2.3 Ethics

The data collection process was approved by the Committee of Ethics at Chilean Construction Chamber (Camara Chilena de la Construcción). Written consent was obtained from the workers before starting the measurement process.

2.4 Statistical Analysis

All the anthropometric data were analyzed using MS Excel and SPSS (v24.0. SPSS Inc., Chicago, IL). An Independent t-test (with a 95% confidence interval) was performed to examine the differences in measurements between the sample from 2016 and 1995. Although the normality of the 1995 sample was not calculated, due the impossibility to access to the full data set [2], t-tests can be considered fairly robust for validity against non-normality [21]. Absolute and relative differences between the two samples were calculated, with positive changes (+) indicating secular increases in mean values, and negative changes (–) indicating secular declines in mean values.

3 Results and Discussions

A of 2346 volunteers' workers was obtained (not randomly selected), exceeding the estimated sample of 1,493 workers.

As it can be seen in Table 1, the average stature was 1710 mm (SD: 65). Additionally, from Table 1 it can also be seen that the average weight was 81.4 kg (SD: 13.1). Average BMI fell into the overweight category (25 $\geq$ BMI $\leq$ 29,9) [22], thus showing that Chilean male workers are following the global epidemic of excessive weight [3, 23–25].

By looking at Table 1, it can be seen that stature (1.3%) had an increase that was considerably smaller than the weight increase (17.5%). This finding also indicates that the Chilean male workers are following the global trend of obesity [26]. As seen in Table 1, the homogeneity of the dimensions expressed by the standard deviations was quite diverse. However, some dimensions had a higher dispersion such as, eye height (63.8), shoulder height (59.9), elbow height (48.3), abdominal depth (39.4), elbow to elbow breadth (47.8) and waist circumference (95.0). The dispersion of the aforementioned dimensions can have an impact in designs. The positive secular trend of Chilean male workers was expected, since it was common on many other populations [3].

As shown in Table 1, out of the 18 anthropometric dimensions compared, 13 presented a positive secular growth for both genders. The ones that had a higher increase were: thigh clearance (18.1%), weight (17.5%), shoulder breadth (14.7%), popliteal height (8.8%); buttock-popliteal length (7.9%) and hip width (5.4%).

The increase observed in the Chilean male adult working population points out that there is a need to update designs, especially those associated with the seated posture. According to Molenbroek et al. [27], those increments have an impact on chair and sitting design. Shoulder breadth, shoulder height sitting, buttock-popliteal distance, and hip width; are directly used as fitting criteria for backrest width, backrest height, seat depth and seat width. Popliteal height also showed an increase and is commonly used

Table 1. Anthropometric data collected in the present study and comparison with the sample from 1995

Variables (mm)	2016		1995		Difference	
	Mean	SD	Mean	SD	Absolute value	%
Weight (Kgs)	81.4	13.1	69.3	11.0	12.1**	17.5
Stature	1710.0	65.0	1688.0	67.0	22.0**	1.3
Body mass index (unit)	27.8	3.9	–	–	–	–
Eye height	1600.7	63.8	1584.0	67.0	16.7**	1.1
Shoulder height	1416.2	59.9	1392.0	60.0	24.2**	1.7
Elbow height	1041.9	48.3	1045.0	49.0	−3.1*	−0.3
Knuckle height	758.8	38.3	742.0	45.0	16.8**	2.3
Sitting height	912.3	35.0	897.0	35.0	15.3**	1.7
Eye height sitting	803.5	33.3	794.0	42.0	9.5**	1.2
Shoulder height sitting	619.0	28.5	602.0	38.0	17.0**	2.8
Subscapular height	460.6	27.2	–	–	–	–
Grip reach. forward reach	740.9	39.0	–	–	–	–
Elbow grip length	340.3	18.5	–	–	–	–
Shoulder-elbow length	374.4	23.2	–	–	–	–
Elbow height sitting	244.6	24.4	254.0	40.0	−9.4**	−3.7
Abdominal depth	267.6	39.4	256.0	40.0	11.6**	4.5
Thigh Clearance	165.4	14.9	140.0	18.0	25.4**	18.1
Buttock-Popliteal Length	496.5	24.6	460.0	31.0	36.5**	7.9
Buttock-knee length	590.4	27.5	575.0	36.0	15.4**	2.7
Knee height	522.6	25.7	–	–	–	–
Popliteal height	436.2	23.2	401.0	28.0	35.2**	8.8
Shoulder (bideltoid) breadth	475.0	30.1	414.0	32.0	61.0**	14.7
Elbow to elbow breadth	487.7	47.8	519.0	49.0	−31.3**	−6.0
Hip breadth	362.5	26.1	344.0	29.0	18.5**	5.4
Hand length	181.1	9.4	–	–	–	–
Hand Breadth (across thumb)	100.9	5.4	–	–	–	–
Hand Breadth (metacarpal)	85.1	4.5	–	–	–	–
Foot breadth	97.2	5.3	–	–	–	–
Foot length	254.0	11.8	–	–	–	–
Head circumference	567.0	16.0	–	–	–	–
Neck circumference	395.0	28.0	–	–	–	–
Waist circumference	925.0	95.0	–	–	–	–

*<0.05. **<0.01

to establish seat height [28]. The mismatch could be greater on products that are used for extended periods of time, such as public transports, since they do not account for secular changes. Office furniture design would also be affected, since the same variables that experienced an increase may affect the chair/desk match. Chilean male workers show an increase of 18,1% on thigh clearance, therefore the under de table space on fixed working stations, desks and production lines can be unproperly fitted. Other designs should also be reviewed, such as industrial workstations and personal protective equipment. The data presented in this study could also be used to purchase and import currently existing products on the market.

Also, from Table 1, comes to attention that three dimensions showed a decrease: elbow breadth (−6%), elbow height sitting (−3.7%) and elbow height standing (−0.3%). Possible explanations could be different productive sectors from which both samples were selected, since the 1995 sample had only three industrial sectors, compared to nine from the current study. Measuring technique and supervision could also be a possible explanation for this variation, since during our measurement project it was observed that subjects modified their posture while being measured, particularly for elbow height (sitting and standing). For example, it was quite often that one of the researchers had to lower the subjects' arm, since the subject shrugged their shoulder when the anthropometer touched the elbow. Additionally, the 1995 study only used two observers that inter-changed functions between them, which could have induced error. The lack of a third observer could have made it more difficult to address any postural deviations of the participants while being measured [29].

Manual measurements were used on the current study. This choice was made to reduce costs but also because it is highly accurate if used properly, meaning that measurers follow extensive practice sessions and training and their intra- and inter-rater error are measured and corrected accordingly [30]. It would have been ideal to also use 3D scanners, but there are none available in Chile. 3D scans, which are a very good complement to assess bio-type, and body/head shapes [31, 32]. Findings of the present paper are somewhat limited by the fact that these are based on the analysis of only two regions of Chile (two most populated ones). Despite these limitations, this is the first update to the anthropometric data of Chilean workers.

4 Conclusions

Anthropometrics is a key input for sustainable and healthy product design. So far, a large amount of studies has been made to improve designs using anthropometrics. Updated data are necessary to make those intentions into a reality. Chileans male workers are now heavier (by 12.1 kg) and taller (by 22.0 mm) than they were in 1995. However, weight increased more (17.5%) than stature (1.3%), which is coherent with the observed global obesity trend. In addition to weight and stature, other anthropometric measures have also increased significantly during the last two decades, such as popliteal height (35.2 mm), hip width (18.5 mm), buttock-popliteal length (40 mm), buttock-knee length (15.4 mm), shoulder height standing (24.2 mm), knuckle height (16.8 mm). Those segmental dimensions that experienced a greater increase are highly associated to seated design match.

A wide range of recent studies have emphasized the importance of up to date anthropometrics in order to produce effective and safe designs. Thus, the data presented in this study shows the need to review designs for Chilean workers, especially public transport seating and office furniture. Other designs such as industrial workstations and personal protective equipment or elevators should also be reviewed in order to understand the level of match covered of the Chilean workers. Finally, we hope that designers and the Occupational Health and Safety community can disseminate and use the data of 2016 presented in this paper, in such a way that they can be applied to specific and safer designs for Chilean male workers

References

1. Nadadur G, Parkinson MB (2013) The role of anthropometry in designing for sustainability. Ergonomics 56(3):422–439
2. Apud E, Gutiérrez M (1997) Diseño ergonómico y características antropométricas de mujeres y hombres adultos chilenos. Prim Jornadas Iberoam Prevención Riesgos Ocup
3. Cole TJ (2003) The secular trend in human physical growth: a biological view. Econ Hum Biol 1(2):161–168
4. Fredriks AM, van Buuren S, Burgmeijer RJ, Meulmeester JF, Beuker RJ, Brugman E et al (2000) Continuing positive secular growth change in The Netherlands 1955–1997. Pediatr Res 47(3):316–323
5. Gutiérrez M, Apud E (1992) Estudio antropométrico y criterios ergonómicos para la evaluación y diseño de mobiliario escolar. Cuad Médico Soc 33(4):72–80
6. Arcaleni E (2006) Secular trend and regional differences in the stature of Italians, 1854–1980. Econ Hum Biol 4(1):24–38
7. Baynouna LM, Revel AD, Nagelkerke NJD, Jaber TM, Omar AO, Ahmed NM et al (2009) Secular trend in height in Al Ain-United Arab Emirates. Econ Hum Biol. 7(3):405–406
8. Bogin B (2001) The growth of humanity. Wiley-Liss, New York
9. Tomkinson GR, Daniell N, Fulton A, Furnell A (2017) Time changes in the body dimensions of male Australian Army personnel between 1977 and 2012. Appl Ergon 58:18–24
10. Schönbeck Y, Talma H, van Dommelen P, Bakker B, Buitendijk SE, HiraSing RA et al (2013) The world's tallest nation has stopped growing taller: the height of Dutch children from 1955 to 2009. Pediatr Res 73(3):371–377
11. Tanner J (1992) Growth as a measure of the nutritional and hygienic status of a population. Horm Res 38:106–115
12. Hauspie R, Vercauteren M, Susanne C (1996) Secular changes in growth. Horm Res 45:8–17
13. Ahacic K, Kåreholt I (2010) Prevalence of musculoskeletal pain in the general Swedish population from 1968 to 2002: age, period, and cohort patterns. Pain 151:206–214
14. Hagen K, Linde M, Heuch I, Stovner LJ, Zwart JA (2011) Increasing prevalence of chronic musculoskeletal complaints. A large 11-year follow-up in the general population. Pain Med 12:1657–1666
15. Dianat I, Kord M, Yahyazade P, Karimi MA Stedmon AW (2015) Association of individual and work-related risk factors with musculoskeletal symptoms among Iranian sewing machine operators. Appl Ergon 51:180–188
16. Spyropoulos P, Papathanasiou G, Georgoudis G, Chronopoulos E, Koutis H, Koumoutsou F (2007) Prevalence of low back pain in Greek public office workers. Pain Phys 10:651
17. Kushwaha D, Kane P (2016) Ergonomic assessment and workstation design of shipping crane cabin in steel industry. Int J Ind Ergon 52:29–39
18. Drury C (2008) The future of ergonomics/the future of work: 45 years after Bartlett (1962). Ergonomics 51(1):14–20

19. ISO. ISO 7250-1: Basic human body measurements for technological design - Part 1: body measurement definitions and landmarks. International Organization for Standardization, Geneva, Switzerland (2008)
20. Portney LG, Watkins MP (2008) Foundations of clinical research: applications to practice. 3rd edn. Pearson/Prentice Hall, Upper Saddle River
21. Zar JH (1999) Biostatistical analysis. Pearson/Prentice Hall, Upper Saddle River
22. WHO (2000). Obesity: preventing and managing the global epidemic. Report of a WHO consultation. WHO Technical report Series 894, Geneva
23. Heineck G (2006) Height and weight in Germany, evidence from the German socio-economic panel, 2002. Econ Hum Biol 4(3):359–382
24. Gordon CC, Bradtmiller B (2012) Anthropometric change: implications for office ergonomics. Work 201241(Suppl. 1):4606–4611
25. Tomkinson GR, Clark AJ, Blanchonette P (2010) Secular changes in body dimensions of royal australian air force aircrew (1971–2005). Ergonomics 53(8):994–1005
26. Matton L, Duvigneaud N, Wijndaele K, Philippaerts R, Duquet W, Beunen G et al (2007) Secular trends in anthropometric characteristics, physical fitness, physical activity, and biological maturation in Flemish adolescents between 1969 and 2005. Am J Hum Biol 19 (3):345–357
27. Molenbroek JFM, Albin TJ, Vink P (2017) Thirty years of anthropometric changes relevant to the width and depth of transportation seating spaces, present and future. Appl Ergon 65:130–138
28. Castellucci HI, Arezes PM, Molenbroek JFM (2014) Applying different equations to evaluate the level of mismatch between students and school furniture. Appl Ergon 45 (4):1123–1132
29. Viviani C, Arezes PM, Bragança S, Molenbroek J, Dianat I, Castellucci HI (2018) Accuracy, precision and reliability in anthropometric surveys for ergonomics purposes in adult working populations: A literature review. Int J Ind Ergon 65:1–16
30. da Silva GV, Halpern M, Gordon CC (2017) Anthropometry of Brazilian air force pilots. Ergonomics 60(10):1445–1457
31. Ball R (2009) 3-D design tools from the SizeChina project. Ergon Des Q Hum Factors Appl 17(3):8–13
32. Pandarum R, Yu W, Hunter L (2011) 3-D breast anthropometry of plus-sized women in South Africa. Ergonomics 54(9):866–875