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Secular changes in the anthropometrics of Chilean workers and its implication in design

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Abstract.
BACKGROUND: Anthropometrics is very important when ensuring a physical match between end users and product or workstations.
OBJECTIVE: The purpose of this study are twofold, to provide anthropometric data for the design of products and to examine the secular changes in the adult Chilean workers in a period of more than 20 years.
METHODS: Nineteen anthropometric measurements from two samples from 1995 and 2016 were compared using independent *t*-test (95% confidence interval), where additionally absolute and relative differences were calculated.
RESULTS: The secular trend observed for Stature is characterized by an increase average of 20 mm and 10.5 mm per decade for females and males, respectively. There is a positive secular trend for both genders, which is observed for most of the selected body measurements. The most pronounced increases were on Weight, Shoulder breadth, Body mass index, Popliteal height; Buttock-popliteal length and Hip width.
CONCLUSIONS: Segmental dimensions that experienced a positive secular trend, together with Weight and Stature, are highly correlated with seating design, addressing the need to review products targeting Chilean adult workers, such as public transport seats, office furniture or industrial workplaces.

Keywords: Design, anthropometry, Chile, secular trends in anthropometry

1. Introduction

Anthropometry is the branch of the human sciences that is concerned with measurements of size, weight and proportions of the human body, with the aim of achieving comfort, optimal fit and usability [1].

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In an ideal design process, anthropometry is used to decide the most relevant dimensions of products and workspaces, for example Popliteal height (height taken from the floor to the back of the knee) is often used to determine the height of chairs [2, 3]. All products for the final user, as well as products for work systems, including clothing, personal protection elements, office stations, vehicles and production lines need to be adjusted to the anthropometric characteristics of the population. This will help to maximize usability and productivity and to minimize the negative effects on end users [4]. However, suppliers do not have data to work with [5].

There is a wide number of studies that have applied anthropometrics in order to achieve optimal design and fitting standards [6–15]. Anthropometric data (or sometimes called anthropometric tables) are a technical reference for the design of products, spaces and work systems. This is especially important because through the digital modeling of anthropometric data with biomechanical criteria, it is possible to simulate the interaction between the users and the system. This allows accommodating the usual human variability, thus helping to prevent injuries and improve productivity [1]. Incorrect products' and workplaces' dimensions coupled with inadequate anthropometric dimensions lead to discomfort, pain and injuries in the neck, shoulders, arms, wrist and back [2, 16, 17].

The first anthropometric database of Chilean workers developed by Apud and Gutiérrez, 1997 [18] has been the only database of body dimensions until very recently. However, using dimensions recommended by Apud and Gutiérrez could be problematic for designing, mainly due to the fact that the data can be outdated because of the secular trend. Secular trend is based on the growth experienced in some populations over a large period of time. It has been defined as an increase in average height between people of the same age along successive generations [19]. Whether this increase is evenly distributed throughout the body or only in certain segments is not yet fully known [20]. 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 [21, 22]. A positive secular growth has been experienced in many countries [4, 19, 23–27] and on specific adult populations, such as Dutch college students [28], US adult civilians and military personnel [29] and Australian air force personnel [24], among others. Positive secular trend is not a constant, it can experience a stoppage 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. The cause for this is still unclear [30]. It is generally assumed that this secular trend is caused by changes in environmental conditions, in particular due to the elimination of factors that would have blocked the full expression of biological potential, such as diseases, inadequate nutrition, poverty and suffering [31]. A positive secular trend is also assumed to reflect changes in living standards and dietary habits [32].

The analysis of the positive secular trend is a very important factor that was considered in the current study since the anthropometric data from Chile correspond to a data collection done in 1995, which may indicate that the data may be outdated. To reinforce the aforementioned and, based on the anthropometric measures of 3,078 Chilean school children evaluated by the authors [33], it was shown that there was an increase in mean Stature, Popliteal height, Hip width and Buttock-popliteal length, in both boys and girls. Thus, it was presumed that a positive secular trend would be present in the Chilean adult population as well.

Outdated anthropometric data and failing to consider the changes resulting from secular trend can jeopardize product and work spaces design and sustainability, since potential mismatch problems will require those designs to be changed, which in turn will elevate the corresponding costs [34].

The aim of the current study is to present anthropometric data for the design of products as well as to examine the design implications of the secular changes observed in a group of anthropometric variables for Chilean workers during a two decades period, between 1995 and 2016.

2. Methods

2.1. Samples

For this study two samples were selected for comparison, one from 1995 [18] and the other one from 2016 [35]. Both studies followed the same measurement protocol [36, 37] and used the same anthropometer (Harpender, Holtain, Crymych, UK) to collect the data. No information was available regarding the weighting scales used to collect Weight data in 1995. Despite the fact that more dimensions were gathered in both samples, only 19 anthropometric measures which were common for both studies were considered for comparison. (Table 1 and Fig. 1). Data extracted from both samples were collected for

Table 1
Anthropometric measurements considered in the studies of 1995 and 2016

Anthropometric measurements	Definition
1. Weight (Kgs)	Total mass (weight) of the body.
2. Stature	Vertical distance between the floor and the top of the head. and measured with the subject erect and looking straight ahead (Frankfurt plane).
3. Eye height standing	Vertical distance from the floor to the inner canthus (corner) of the eye (head in Frankfurt plane).
4. Shoulder height standing	Vertical distance from the floor to the acromion.
5. Elbow height standing	Taken with a 90° angle elbow flexion. as the vertical distance from the bottom of the tip of the elbow (olecranon) to the floor.
6. Knuckle height	Vertical distance from the floor to metacarpal III (i.e. the knuckle of the middle finger).
7. Sitting height	Vertical distance between subject's seated surface to the top of the head. and measured with the subject erect and looking straight ahead (Frankfurt plane).
8. Eye height sitting	Vertical distance between the sitting surface to the inner canthus (corner) of the eye (head in Frankfurt plane).
9. Shoulder height sitting	Vertical distance from subject's seated surface to the acromion.
10. 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.
11. Abdominal depth	Maximum horizontal distance from the vertical reference plane to the front of the abdomen in the standard sitting position.
12. Thigh clearance	Vertical distance from the highest uncompressed point of thigh to the subject's seated surface.
13. Buttock-popliteal length	Horizontal distance from the popliteal surface to the rearmost point of the buttock.
14. Buttock-knee length	Horizontal distance from the foremost point of the knee-cap to the rearmost point of the buttock.
15. Popliteal height	Vertical distance from the floor or footrest to the posterior surface of the knee (popliteal surface).
16. Shoulder breadth	Distance across the maximum lateral protrusions of the right and left deltoid muscles.
17. Elbow breadth	Maximum horizontal breadth across the elbows.
18. Hip width	Horizontal distance measured in the widest point of the hip in the sitting position.
19. Body mass index	Weight in kilograms (kg) divided by his or her height in meters squared.

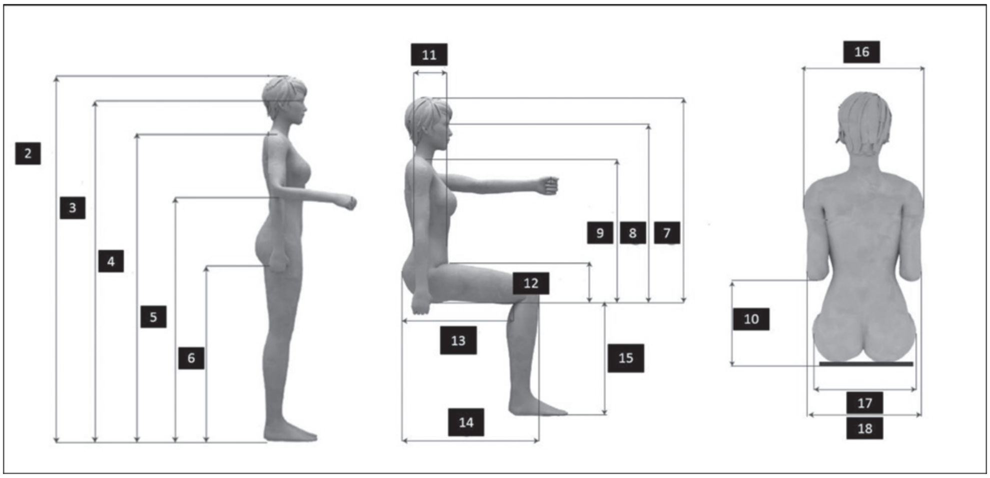

Fig. 1. Anthropometric measurements considered for comparison.

ergonomic purposes, specifically for the design and evaluation of workplaces.

2.2.1. Sample from 1995

Although the publication year of the anthropometric tables made by Apud and Gutierrez was 1997 [18], the data was actually collected in 1995 (Gutiérrez personal communication). The sample from 1995 included 3,765 Chilean workers from the Concepción Region (1,735 females and 2,030 males), and the collection of 20 and 22 anthropometrics measures for females and males, respectively. Body mass index (BMI) was calculated for the present study using the average of weight and stature. The samples consisted of workers from three economic activity sectors (Agriculture and fishing; Manufacturing; and Communal and personal services).

The measurement process was carried out by two people, which were able to switch between roles, i.e. from measurer to recorder and vice-versa. Before starting to collect data, the two measurers/recorders underwent a training session, where they were provided with the definitions of each body dimension and, each measurement procedure, was demonstrated by an experienced anthropometry specialist. In the laboratory, the execution of the measurements was verified and corrected and, subsequently, field execution was monitored. Finally, quality data was assessed by analyzing and deleting all data without the range of ± 3 standard deviations regarding the average (considered outliers).

2.2.2. Sample from 2016

Data from the sample of 2016 was collected by the authors of this article as a part of a larger research project, which include the collection of a total of 32 anthropometrics measures. Data were collected on 2,946 workers (600 female and 2,346 male) from the two most populated regions of Chile (Valparaíso and Metropolitana) distributed by 9 economic activity sectors (Agriculture and fishing; Mining; Manufacturing; Electricity; Construction; Commerce; Transport and communications; Financial services; and Communal and personal services).

Data gathering was done by six physiotherapists, divided in two teams. Previous to field measurements, teams underwent a one-week training session, including a theoretical approach to anthropometrics, as well as practical instructions lectures. Practice was done over a period of two weeks until consistency between measurers was obtained. After the training period, a pilot study was developed with a sample of 25 volunteers, which was 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 [38], namely an ICC ≥ 0.50 was interpreted as being moderate and an ICC ≥ 0.75 was interpreted as being strong. The results from Table 2 show that measurers have a strong value of inter- and intra-reliability.

Table 2
Intra and inter-measurer reliability (ICC values)

Anthropometric dimension	Measurer 1	Measurer 2	Inter-measurers
Weight	0.999	0.997	0.990
Stature	0.999	0.996	0.984
Eye height standing	0.788	0.898	0.782
Shoulder height standing	0.941	0.912	0.930
Elbow height standing	0.901	0.703	0.793
Knuckle height	0.980	0.983	0.970
Sitting height	0.951	0.936	0.937
Eye height sitting	0.788	0.898	0.782
Shoulder height sitting	0.941	0.912	0.930
Elbow height sitting	0.901	0.703	0.793
Abdominal depth	0.953	0.949	0.942
Thigh clearance	0.864	0.866	0.879
Buttock-popliteal length	0.910	0.789	0.878
Buttock-knee length	0.977	0.895	0.956
Popliteal height	0.940	0.967	0.929
Shoulder breadth	0.974	0.982	0.975
Elbow breadth	0.952	0.937	0.948
Hip width	0.781	0.761	0.784

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.

2.2. Statistical analysis

An independent *t*-test (with a 95% confidence interval) was performed to examine the differences in the considered measurements between the samples of 1995 and 2016. Although the normality of the 1995 sample was not calculated, due the impossibility to access to the full data set, since according to the authors the raw data was missing (Gutierrez personal communication), where only percentile values, average and standard deviations were available. Despite that, *t*-tests can be considered fairly robust for validity against non-normality [39], thus they were used for making the comparisons. Furthermore, in a large sample, as presented in the currently study, the *t*-test is a useful default tools for analyzing differences and trends in many types of data, not just those with normal distributions [40]. It is important to highlight that to be able to perform the *t*-test for BMI the researchers assumed that standard deviations from the sample of 1995 is the same of the 2016, since BMI was not reported.

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. Finally, to express the observed change per decade, the absolute difference was divided by 2.1, since the difference between the two studies was 21 years or 2.1 decades.

3. Results

As shown in Tables 3 and 4, out of the 19 anthropometric compared dimensions, 14 presented a positive secular growth for both genders. The body dimensions with a greater % increase (for both female and male) along this 20-year period were:

- Weight (F: 10.3% M: 17.5%),
- Body mass index (F: 4.3% M: 14.4%);
- Shoulder breadth (F: 11% M: 14.7%);
- Popliteal height (F: 13.7% M: 8.8%);
- Buttock-popliteal length (F: 9.1% M: 7.9%);
- Hip width (F: 7.3% M: 5.4%).

Other dimensions that showed an increase on Chilean workers for both genders were Knuckle height (F: 4.5% M: 2.3%), Buttock-knee length (F: 2.3% M: 2.7%), Shoulder height standing (F: 2,8% M: 1,7%), Sitting height (F: 1.8% M: 1.7%), Eye height standing (F: 1.9% M: 1.1%) and Thigh clearance (F: 1.7% M: 18.1%).

It can also be seen in Tables 3 and 4 that five dimensions showed a decrease. It is interesting to note that two dimensions showed a decrease for both genders. Those dimensions were Elbow breadth (F: –9.5% M: –6%) and Elbow height sitting (F: –8.3% M: –3.7%). If we focus exclusively on females, it can be seen in Table 3 there was a decrease on two dimensions, Eye height sitting: (–0.4%) and Abdominal depth: (–5.1%). By observing Table 4, it can be seen that males showed a decrease exclusively on the Elbow height standing (–0.3%). Possible causes are further explained in the Discussion.

By looking at Tables 3 and 4, it can be also seen that Stature increase (F: 2.9% M: 1.3%) was considerably smaller than Weight increase (F: 10.3% M:17.5 %) for both genders.

From Fig. 2 it can also be seen that Chilean workers had an average increase in Stature of about 15 mm per

Table 3
Anthropometric female data from the 2016 and 1995 studies

Anthropometric dimension (mm)	2016		1995		Difference	
	Mean	SD	Mean	SD	Absolute value (95% CI)	%
Weight (Kgs)	66.87	12.00	60.7	10.1	6.2**(5.09, 7.24)	10.3
Stature	1593.20	60.60	1549.0	62.0	44.2**(38.53, 49.86)	2.9
Eye height standing	1488.31	60.39	1461.0	57.9	27.3**(21.75, 32.86)	1.9
Shoulder height standing	1316.14	55.78	1280.0	50.6	36.1**(31.07, 41.20)	2.8
Elbow height standing	977.31	46.34	966.0	39.1	11.3**(7.16, 15.45)	1.2
Knuckle height	711.37	34.79	681.0	36.6	30.4**(27.09, 33.64)	4.5
Sitting height	859.86	32.38	845.0	33.5	14.9**(11.82, 17.89)	1.8
Eye height sitting	754.97	31.99	758.0	35.6	–3.0 (–6.09, 0.03)	–0.4
Shoulder height sitting	582.80	26.53	577.0	31.9	5.8**(3.19, 8.40)	1.0
Elbow height sitting	243.97	24.78	266.0	31.3	–22.0**(–24.50, –19.55)	–8.3
Abdominal depth	238.18	49.41	251.0	39.7	–12.8**(–17.19, –8.44)	–5.1
Thigh clearance	151.54	15.87	149.0	17.7	2.5** (1.01, 4.06)	1.7
Buttock-popliteal length	479.04	24.62	439.0	29.0	40.0**(37.64, 42.43)	9.1
Buttock-knee length	559.83	26.60	547.0	30.0	12.8**(10.27, 15.38)	2.3
Popliteal height	403.75	21.29	355.0	24.0	48.8**(46.70, 50.79)	13.7
Shoulder breadth	431.76	34.21	389.0	27.0	42.8**(39.73, 45.78)	11.0
Elbow breadth	435.18	54.52	481.0	48.0	–45.8**(–50.73, –40.90)	–9.5
Hip width	390.66	32.04	364.0	28.0	26.7**(23.77, 29.54)	7.3
Body mass index	26.40	4.70	25.30	4.70	1.1**(0.66, 1.53)	4.3

**<0.05. **<0.01, CI: confidence interval.

Table 4
Anthropometric male data from the 2016 and 1995 studies

Anthropometric dimension (mm)	2016		1995		Difference	
	Mean	SD	Mean	SD	Absolute value (95% CI)	%
Weight (kgs)	81.4	13.1	69.3	11	12.1** (11.38, 12.81)	17.5
Stature	1710.0	65.0	1688	67	22.0**(18.07, 25.92)	1.3
Eye height standing	1600.7	63.8	1584	67	16.7**(12.80, 20.59)	1.1
Shoulder height standing	1416.2	59.9	1392	60	24.2**(20.63, 27.76)	1.7
Elbow height standing	1041.9	48.3	1045	49	–3.1*(–5.99, –0.20)	–0.3
Knuckle height	758.8	38.3	742	45	16.8**(14.30, 19.29)	2.3
Sitting height	912.3	35.0	897	35	15.3**(13.22, 17.37)	1.7
Eye height sitting	803.5	33.3	794	42	9.5**(7.22, 11.77)	1.2
Shoulder height sitting	619.0	28.5	602	38	17.0**(14.98, 19.01)	2.8
Elbow height sitting	244.6	24.4	254	40	–9.4**(–11.40, –7.39)	–3.7
Abdominal depth	267.6	39.4	256	40	11.6**(9.23, 13.96)	4.5
Thigh clearance	165.4	14.9	140	18	25.4**(24.41, 26.38)	18.1
Buttock-popliteal length	496.5	24.6	460	31	36.5**(34.82, 38.17)	7.9
Buttock-knee length	590.4	27.5	575	36	15.4**(13.47, 17.32)	2.7
Popliteal height	436.2	23.2	401	28	35.2**(33.66, 36.73)	8.8
Shoulder breadth	475.0	30.1	414	32	61.0**(59.14, 62.85)	14.7
Elbow breadth	487.7	47.8	519	49	–31.3**(–34.17, –28.42)	–6.0
Hip width	362.5	26.1	344	29	18.5**(16.85, 20.14)	5.4
Body mass index	27.80	3.90	24.30	3.90	3.5**(3.27, 3.73)	14.4

*$p<0.05$ **$p<0.01$, CI: confidence interval.

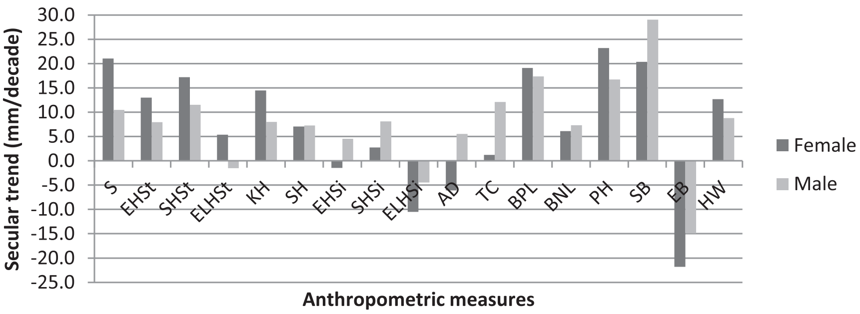

Fig. 2. Secular trend per decade in the anthropometric measurements. Stature (S), Eye height standing (EHst), Shoulder height standing (SHst), Elbow height standing (ELHst), Knuckle height (KH), Sitting height (SH), Eye height sitting (EHsi), Shoulder height sitting (SHst), Elbow height sitting (ElHst), Abdominal depth (AD), Thigh clearance (TC), Buttock-popliteal length (BPL), Buttock-knee length (BNL), Popliteal height (PH), Shoulder breadth (SB), Elbow breadth (EB), Hip width (HW).

decade, specifically 20 mm per decade for women and 10.5 mm per decade for men.

These findings show a very particular phenomenon, since despite the fact that Chilean male workers are taller than female workers, the latter experienced a stature increase that doubled the increase experienced by males over the last 2 decades.

Tables 3 and 4 also show that the dispersion of the dimensions was higher on women, since the standard deviations showed an increase on eight dimensions for women (Weight, Eye height standing, Shoulder height standing, Elbow height standing, Abdominal depth, shoulder breadth, Elbow breadth and hip width) and only on one (Weight) for men.

4. Discussion

The positive secular growth experienced by Chilean workers is a finding that was already somehow expected, since it has occurred in other countries and populations as well [19].

Stature and Weight experienced the highest increase of all the observed dimensions, with Weight showing the most significant for both genders. Also, BMI experienced a significant increase, especially in males. These results are similar to those obtained for US civilians [29], Dutch university students [28] and Swedish adult populations [4]. This could indicate that the Chilean adult population is following the global trend of obesity [41], which has been constantly increasing [42].

Stature secular trend of females nearly doubled the one of males. This finding was also seen in an anthropometric survey in Chilean schoolchildren, where girls had a higher secular growth than boys [33]. According to Castellucci et al. [33], there was a secular growth per decade of 14 mm and 11 mm for girls and boys, respectively. The stature increase was also associated with an increase in popliteal height, which was 10 to 30 mm higher; hip width that was 22 mm higher and buttock-popliteal distance that was 21 mm higher. These results conflict with those presented by Cole [19], who indicated that in the 20th century, the women's trend has been less clear than the men's trend. This has also been the case among Swedish adults [4], where stature has increased 0.9 mm/year for females and 1.4 mm/year for males. These numbers are in agreement with general secular trend growth rate figures [36] and with the growth rate of Italians [23]. Our findings are somehow similar to the ones obtained by Agarwal et al. [43], who concluded that women experienced a bigger increase in their stature than men. Although focused on children and adolescents, they reported growth parameters on over 20,000 children from 23 schools in various cities in India, showing that in children and adolescents, a secular trend was reported (19 years) revealing an increase in average stature of 21 mm per decade for boys, and 27 mm per decade for girls at 17 and 14 years old, respectively.

One possible explanation for the clear Stature increase of Chilean women could be that gender equality has improved in Chile since the country got open to democracy in 1990, with many social programs focusing on women and girls only, such as women's health, education scholarships, entrepreneurship funds, social security, and other social benefits [44, 45]. Since male workers had an increase in their stature and have been somehow "privileged" compared to women, it is likely that females caught up by expressing their biological potential through the last two decades. This would make sense, since relevant research on the subject states that deprivation and adverse conditions have a negative effect on human growth, such as inability to access good healthcare, education, nutrition and a higher incomes [19, 31, 46, 47]. Another author found similar trend in children and adolescents in India, where women's education programs and social benefits had increased life expectancy above national average in the Kerala province, which affected positively the growth of children [48].

It would be interesting to revisit data 10 years from now and see the effects on secular trend of social programs addressed to women, in order to see their impact on women's growth compared to men. Strong equity policies focused on women have been currently implemented in Chile since the last 4 years, including the creation of a Women‘s and Gender Equity Ministry just two years ago [49]. For example, a study conducted by Schwekendiek and Jun [50] analyzed, among other factors, the income per capita, and the consumption of meat and milk in South Korea, and compared the Korean male adult stature trend with the previously stated variables. As the indicated authors, we also believe that better living conditions are a possible explanation for the observed trend in Chile, since transition of health problems related to child malnutrition have been replaced with chronic non-transmissible illnesses associated with obesity [51]. This is typical and coherent with the obesity epidemic that affects many countries that have achieved (or are in the process of achieving) better living standards [19, 47]. Cole [19] also suggested that, since the 90's, stature in developed countries is generally stable compared to Weight. In the case of Chilean adult working population, this trend can also be seen, even when stature increased, it was considerably smaller than the Weight and BMI increase, thus showing that Chile is experiencing a secular change trend somehow similar to developed countries. These findings clearly adds up to the trend of increasing mass relative to stature of individuals worldwide, which by its turn will impact on the design of seat dimensions [28].

It is usual to see anthropometrics comparisons among different populations, mainly to see if relevant differences or similarities could result in some similar designs or the need to create new ones [52–55]. The secular increase shown by Chilean workers was expected and is somehow comparable to other populations, such as the Swedish and Dutch adult populations. According to relatively recent research [4], the Swedish adult population experienced a significant increase on Popliteal height (F: 11.8% M: 13%), Hip breadth (F: 13,4% M: 8,3%) Shoulder breadth (F: 8.9% M: 2.5%) and Weight (F: 9.8% M: n/a); which was more or less similar to the one experienced by the Chilean adult population. The Dutch adult population also showed an increase on similar dimensions, however, it was more discrete than the one found with Chilean adults, with the most relevant increase occurring for body dimensions such as Hip width (F: 7% M: 7%), Thigh clearance (F: 5%

M: 5%), Elbow height seated (F: 10% M: 10%), Eye height seated (F: 1.5% M: 1.5%) and Popliteal height (F: 0.5% M: 1%) [28]. This different scenario for the Dutch population might be explained by the stoppage in growth experienced in this country [56] and the fact that this population has probably achieved their maximal genetic potential, mainly due to better living conditions (Tanner, 1992). Other dimensions that showed an increase on Chilean workers for both genders were Knuckle height (F: 4.5% M: 2.3%), Buttock-knee length (F: 2.3% M: 2.7%), Shoulder height standing (F: 2,8% M: 1,7%), Sitting height (F: 1.8% M: 1.7%), Eye height standing (F: 1.9% M: 1.1%) and Thigh clearance (F: 1.7% M: 18.1%).

Regarding the design implications of these changes, the positive secular trend justifies the need to update designs, especially those associated with the seating. According to Molenbroek et al. [28], increments on the dimensions described previously would definitively have an impact on chair and seating design in general. For example, 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. Another very relevant measure to the seated posture and design is Popliteal height, used to establish the seat height [57]. According to Molenbroek et al. [28], accommodation could be lower on products with significant longevity, such as airplanes, buses and train seats, where secular changes may not be accounted for due to a lack of update on the changes of their respective designs. For example, besides regular sitting criteria, buttock-knee distance is used to design seat pitch on tandem seats (distance between the front and back seats) and is critical for the determination of leg room [28]. According to other authors, passengers' comfort in aircraft seat design [58] is related to seat widths and depths and have a significant impact on the users' perceptions of comfort [9]. The increase of the anthropometric dimensions previously mentioned also have an impact on office furniture design, especially non-adjustable ones, since the same variables that experienced an increase may affect the chair/desk match. For example, the case of Chilean males shows an increase of 18.1% on thigh clearance, therefore table leg clearance on fixed working stations, desks and production lines could be unfitted specially for Chilean males. Thus, public transport and seated design standards for Chilean adult population should be reviewed with the data presented on this paper in order to analyze and identify possible mismatches. There is no doubt that many other designs should be reviewed, especially those using the dimensions presented on this paper such as tools [59], industrial workstations [60, 61] and personal protective equipment [62]. Note that any percentile value can be calculated using basic normal distribution statistics (Z-score equation), since the total sample size, average values and standard deviations are presented for each dimension. Therefore, any dimensional value corresponding to a given percentile can be obtained in order to design, for example, any of the values required for seating designs previously described.

As previously described in the Results section, Elbow breadth and Elbow height sitting showed a decrease in both genders, while females showed a decrease in Eye height sitting and Abdominal depth. Males showed a decrease exclusively on the Elbow height standing. It would be expected that if Weight and Stature increase, segmental dimensions associated to width, breadth, depth and length, should increase as well, however in practice, the fact is that it is possible to see a decrease. In the case of Hanson et al. [4], after 48 anthropometric dimensions were collected and compared against previously collected dimensions used in Swedish anthropometrics, the authors found a decrease in 14 dimensions, 11 for women and 3 for men. The most significant changes were seen on dimensions associated with Weight, particularly on women, even when the weight for Swedish adult women increased more than stature, such as Abdominal depth sitting (F: –4% M: 4.3%) and Thigh clearance (F: –5.2% M: –3.3%) [4]. Thus, there may not necessarily exist a direct relation between Weight/Stature and their related segmental dimensions as stated by Steenbekkers [20]. It came to the surprise of the research group that some dimensions had a negative secular growth on female workers only (eye height and abdominal depth), male workers only (elbow height sitting) and for both female and male workers (elbow height sitting and elbow breadth). One possible explanation of the variations could be the measuring technique and the subjects' posture while being measured. From our own experience, it was previously acknowledged that several subjects modified their posture in order to accommodate the "arms" of the anthropometer while being measured. For instance, it is common that the researchers had to lower the subjects' arm while measuring elbow height sitting, since the subjects tend to shrug their shoulders when the anthropometer touched the elbow. In fact, according to Fisher and Byrne [63], women are more sensitive to perceive adjacent overlap as an intrusion into their personal space, explaining in part the fact why women had more negative trends than men. Further research should address the causes of inverse variations of related measures that otherwise should vary proportionally, for example, an increase in stature and eye height standing should lead to a corresponding increase in sitting height and eye height sitting or increase in obesity should lead to a corresponding increase in abdominal depth. Previous studies have discussed the relevance of procedures and tools used as possible variation sources, which could be considered as a base for addressing issues regarding inverse variations of related anthropometric dimensions [64].

The dispersion shown by females presents a challenge for future designs focused specially on women. The stature and segmental increases on Chilean working women's anthropometrics, and their dispersion, could definitively have an impact on women products or in products that use male anthropometrics for design but are also used by women, such as firefighting gear [65].

Top notch anthropometric research has been used for delivering databases in order to designs that are safe and efficient. This has been the case for even with specific populations, such as Brazilian air force personnel [11], Colombian flower farmers [66], electricity workers [53] and even special populations [13]. Hitherto the dimensions used for designing or purchasing equipment for Chilean workers have more than 20 years old, therefore the data presented on this study makes a contribution to any Occupational Health and Safety/ergonomics practitioner, designer or manufacturer aiming at introducing any product or workstation for Chilean workers. Finally, future work should gather dynamic anthropometric data, such as range of motion, angles between body parts, spinal curvature, center of pressure among others, in order to have a full spectrum of information that can be used for design purposes [67].

5. Conclusions

Chileans female and male workers have more Weight and are taller than in 1995. However, Weight and BMI increased more than Stature, which was similar with the global obesity trend. Women have experienced a Stature increase which is nearly the double of the one observed for men. These findings are interesting and show that it might be worth to conduct further research that allows to understand why women had a higher secular growth in Stature than men (fact also observed on Chilean school children). The research team believes that this may be attributed to better living conditions, social programs and education access that addressed specifically women. Regarding gender differences among Chilean workers, it was observed that male workers have larger measurement values than women, with the exception of Hip width, which is common on all populations. Besides stature, segmental anthropometric measures have increased significantly over the observed time, such as Popliteal height, Hip width, Buttock-popliteal length, Buttock-knee length, Shoulder height standing, Knuckle height, among others. Those segmental dimensions that experienced a greater increase are highly associated to seating accommodation.

Several recent studies have pinpointed the relevance of using updated anthropometrics in order to create better designs. Therefore, the findings of this study justify the need to review designs aimed for Chilean workers, especially public transport seating and office furniture. Other designs like industrial workstations and personal protective equipment should also be reviewed in order to understand the level of accommodation experienced by Chilean workers. Finally, we hope that designers and the OHS community at large can spread and use the information presented here, which will certainly result in more specific and safer designs for Chilean workers.

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Conflict of interest

None to report.

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