A RE-DESIGN PROJECT: CORRECTION OF AN OUTDOOR FITNESS EQUIPMENT'S DESIGN ACCORDING TO ITS USERS'S ANTHROPOMETRIC AND BIOMECHANICAL DATA

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BİR YENİDEN TASARIM PROJESİ: BİR DIŞ MEKAN FİTNESS ALETİ TASARIMININ KULLANICILARININ ANTROPOMETRİK VE BİYOMEKANİK VERİLERİNE UYGUN OLARAK DÜZELTİLMESİ

Anahtar Kelimeler

Ergonomi, Antropometri, Biyomekanik, Dış mekan fitness aleti, Endüstriyel tasarım, Kullanıcı odaklı Tasarım, Düz çizgi mekanizmaları

Öz

Bu çalışmanın amacı dış mekan fitness aleti kullanıcılarının antropometrik ölçülerinin belirlenerek, hali halızırda kullanımda olan bir dış mekan fitness aletinin kullanıcılara uygun olarak yeniden tasarlanmasıdır. Çalışmaya, Eskişehir ilinde ikamet eden 100(50 kadın ve 50 erkek) dış mekan fitness aleti kullanıcısı gönüllü olarak katılmıştır. Katılımcıların yaşı 18 - 79 arasında olup, yaş ortalamaları 31'dir (SD: 1,15277). Çalışmada boy, omuz yüksekliği, kol yana uzanım mesafesi, yumruk yüksekliği, ön kol uzunluğu, üst kol uzunluğu, omuz-parmak ucu uzunluğu, diz yüksekliği, aşık kemiği yüksekliği ve el uzunluğu ölçüleri toplanmıştır. Toplanan ölçüler, herhangi bir antropometrik uyumsuzluk olup olmadığını belirlemek adına halihazırda kullanımda olan dış mekan fitness aleti ölçüleriyle karşılaştırılmıştır. Elde edilen veriler yetişkin kullanıcıların vücut ölçüleriyle, mevcut dış mekan fitness aleti ölçülerinin birbiriyle uyumlu olmadığını göstermiştir. Sonrasında, mevcut fitness aletinin hareket çıktısı, biyomekanik limitlerle karşılaştırılmıştır. Karşılaştırma sonucu yaralanmalara neden olabilecek bir uyumsuzluk tespit edilmiştir. Tespit edilen bu uyumsuzluklar toplum sağlığını tehlikeye attığından, bir dış mekan fitness aleti, FE02 Stepper, kullanıcıların antropometrik verilerine ve biyomekanik limitlerine uygun olarak, sonraki tasarımlara örnek olabilmesi adına, yeniden tasarlanmıştır.

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Keywords

Ergonomics, Anthropometry, Biomechanics, Outdoor fitness equipment, Industrial design, User-centred design, Straight-line mechanisms

Abstract

The aim of this study is to determine the anthropometric measurements of the users of outdoor fitness equipment and to re-design of an in use outdoor fitness equipment according to these measurements. A total of 100 (50 male and 50 female) outdoor fitness equipment users, living in Eskisehir, Turkey, voluntarily participated in the study. Their ages ranged from 18 to 79 years and the mean of their ages were 31,2 (SD: 1,15277). The following human body dimensions were measured: stature, shoulder height, side-arm reach, fist (knuckle) height, forearm length, upper arm length, shoulder-fingertip length, knee height, malleolus height and hand length. The anthropometric measures of the adults and the outdoor fitness equipment' dimensions were compared in order to identify any incompatibility between them. The data indicated a mismatch between the adults' bodily dimensions and the outdoor fitness equipment available to them. Later on, in use fitness equipment's motion output compared with biomechanical limits. Also, a mismatch was found between the motion output and biomechanical limits which might cause injuries. As these mismatches endanger public health, an outdoor fitness equipment, FE02 Stepper was re-designed according to its users' anthropometric data and biomechanical limits as an example.

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1. Introduction

Anthropometry literally means *measurement of a human*. In physical anthropology, it refers to one aspect of human variation: the different body sizes and proportions of individuals belonging to different populations. Also it specifically refers to the measurement of living individuals. The data which is the resource for ergonomics is obtained by the help of anthropometrics, which is very important in each phase of the design for humans. The discipline of ergonomics not only analyses the relations of people with the environment by an interdisciplinary understanding but also checks the convenience of behavioural principles of the human body for the usage of every type of tool in different conditions, especially working and exercising. Equipment that are designed according to ergonomic principles help to increase the efficiency of related activities. Besides, the ergonomic equipment intend to decrease the risk of fatigue and injury. However, anthropometric and ergonomic data being differentiate from society to society and even from person to person, and therefore design has to take into consideration these variables. Design of tasks and equipment, based on the concept of 'fitting the task to the person', requires that there must be a match between the requirements of the tasks and the physical and mental capabilities of the people performing them (Imrhan et al., 2009). Design studies help to meet these varieties by producing convenient products. The unique way of satisfying people is considering different physical characteristics and applying effectively into design process.

Donald A. Norman, writer of The Design of Everyday Things (2002) states that injuries aren't users' fault; it's the fault of the design. Thereof, the safety of products is one of the main responses of designers, for fulfilling the safety, designing the choreography of the product's movement is a designers' response too. Outdoor fitness equipment are kind of machines with respect to statement of Reuleaux's (1963) definition: a machine is a collection of mechanisms arranged to transmit forces and do work. Outdoor fitness equipment are good examples for human-machine interactions as industrial products in the context of 'fitting task to the person'. Another major requirement of outdoor fitness equipment is injury prevention, in addition to that, an optimal match between the users' requirements and the equipment characteristics is essential (Dabnicki, 1998).

Yet, it is hard to say that Turkish made products being designed according to ergonomic data due to lack of researches. As a result of the poor quality, un-ergonomically designed products cause harmful outcomes for their users such as non-essential movements and / or overstrain (Özkul, 1999).

The literature review showed that researches on the relations between ergonomic data and products in Turkey are a few. Sabancı (1981) conducted a study on the ergonomic qualities of agricultural tractors whilst Bayık (1992) in addition to the ergonomic conditions, like noise and weather conditions, also studied the anthropometry of the operator seat. Su (1985) with the help of 25 anthropometric measurements taken on 2000 Turkish soldiers conducted a study to determine the standards of military uniforms. Kayış (1986) conducted a study to determine the anthropometric data taking 15 measurements on 3584 pupils aged between 6-13 years. This study was later revised and turned into a database for designing of classroom furniture by Kayış (1987) and Kayış and Özok (1991). In 1989, Turkish army men's measurements were taken by Kayış and Özok. The total number of the participants of this study was 5109. Gönen and Kalınkara (1993) took 20 anthropometric measurements of 204 students and the results were used to form a database for designing products for schools, libraries, laboratories, theatres and conference halls. Akın and Sağır (1998) investigated the anthropometric characteristics of 245 primary school girls aged between 9-10 years by taking measurements in 14 dimensions. The survey undertaken by Dizdar analysed the accidents in the context of ergonomics and presented the results in 2001. Burdurlu et al. (2006) examined the anthropometric characteristics of a total of 668 Turkish students (336 girls and 332 boys) between 12-15 years attending high schools in Ankara/Turkey. The data obtained by this study had the purpose of determining optimal measurements of classroom furniture such as desks, chairs, writing boards and clothes hangers in the future. In 2006 Karakuş and Kılınç's article "Posture and Sportive Performance" was published. The aim of the study was to examine the importance of the posture, accepted as an indicator of human body structure, in a sportive performance. Güleç et al. (2009) collected a total 37 anthropometric measurements from 2100 subjects in order to create a data pool for designing and producing everyday life artefacts. The purpose of İşeri and Arslan's paper is to estimate the anthropometric characteristics of the Turkish population by geographical region, age and gender. A survey of 4205 samples consisting of 2263 male and 1942 female civilian subjects was done at 2007 and published in 2009. A total 37 measurements that are commonly used in industry were taken by İşeri and Arslan (2009). In 2011, Kalınkara et al. collected 14 anthropometric measures from 296 university students to eliminate design errors of classroom furniture which may cause health problems.

Pheasant (1996) points out the importance of ergonomic and anthropometric data in design as:

> In ergonomics and anthropometrics, a constraint is an observable, preferably measurable, characteristic of human beings, which has consequences for the design of a particular artefact. A criterion is a standard of judgement against which the match between user and artefact may be measured. We may distinguish various hierarchic levels of criteria. Near the top are overall desiderata such as comfort, safety, efficiency, aesthetics, etc., which we may call high-level, general, or primary criteria. In order to achieve these goals, numerous low-level, special, or secondary criteria must be satisfied. The relationships between these concepts may be illustrated by way of example. In the design of a chair, comfort would be an obvious primary criterion; the lower leg length of the user imposes a constraint upon the design since, if the chair is too high, pressure on the underside of the thigh will cause discomfort (Pheasant, 1996, p. 21)

Botha and Briger (1998) state that the lack of properly designed machines and equipment may reduce the work performance and increase the frequency of work-related injuries. Also according to Aspelund (2006) designs have needs; the following needs are listed in the order of priority: functionality, reliability, usability, proficiency and creativity. As reliability goes hand in hand with safety (Aspelund, 2006) and usability goes hand in hand with user characteristics, for the fulfilment reliability and usability needs products must be designed according to ergonomic and anthropometric data.

In order to prevent injuries and / or increase performance, outdoor fitness equipment which have started to be used by Turkish society widespread should be inspected, and if there is a mismatch should be re-designed according to Turkish society with the help of anthropometric data that has been obtained under scientific conditions defined by scientific resources. With regard to their functionality, outdoor fitness equipment are industrial products as they being mass produced by industry through a design process with elements concerning industrial design, such as functionality, visualization, material knowledge, ergonomics and production methods. Within this concept, it's far from reality to think of designing outdoor fitness equipment which are industrial products, independently from ergonomic principles and anthropometric data.

With regard to this fact, an anthropometric research carried out for this study to define the general anthropometric measurements of the people living in the province of Eskisehir, Turkey where the outdoor fitness equipment is produced and distributed. The anthropometric measures obtained with the results of this research are used to design of a sports equipment, FE02 Stepper.

2. Methods

An adequate description of the human body may require over 300 dimensions (Pheasant, 1986), yet the scope of this study was limited by time and financial restrictions as well as the basic anthropometric requirements of the product design itself. Thus, a total ten body dimensions were selected according to design needs: stature, shoulder height, side-arm reach, fist (knuckle) height, forearm length, upper arm length, shoulder-fingertip length, knee height, malleolus height and hand length. Also one body dimension, shoulder breadth was found by using Pheasant's 'ratio scaling' technique. This technique assumes that although different samples drawn from a particular 'parent' population may vary greatly in size, they are likely to be relatively similar in shape. Thus we have detailed body-part measurements for an equivalent population or population sample; we may use the former to 'scale up' the latter (Pheasant, 1996). A detailed validation study of this technique is described in Pheasant (1982). The 1st and 99th percentile values of some dimensions drawn from six different surveys were estimated from knowledge of only the parameters of stature in the survey concerned. In many cases the estimates were within the confidence limits of the original survey (Pheasant, 1996)

The data was summarised and analysed with the aid of the SPSS v13 software on a desktop computer. Descriptive statistics (Tables 1 and 2) for each anthropometric dimension are given as mean, standard deviation and selected percentiles for male and female in cm and the results of step height research (Table 3) are given as percentiles. After the obtained measurements compared with the outdoor fitness equipment's measurements for potential mismatches.

Not only outdoor fitness equipment but also most of products have a kind of movement that provides to achieve to desire task. In order to match users' motion characteristics, the outdoor fitness equipment's motion output is inspected and is compared with lower extremity biomechanics. To do so angular kinematic values during the exercise are collected with the help of Lafayette extendable goniometer.

The study is conducted between 2007 and 2011.

2.1. Participants

Anthropometric measurements were collected from 100 (50 male and 50 female) adults, living in Eskisehir, Turkey. The participants were selected among a total 103 volunteered subjects who has been using the outdoor fitness equipment regularly to exercise. In order to achieve equal numbers of participants from each gender, three female participants were excluded randomly from the study. Ages of participants were 18 to 79 and the mean of their ages were 31,2 (SD:-1,15277). Anthropometric measurements were taken with people standing (Figure 1) by Holtain Anthropometer at a place convenient for the volunteer and the study itself. During the measurement, subjects were required to wear only shorts and sleeveless t-shirt. The dimensions were measured without shoes.

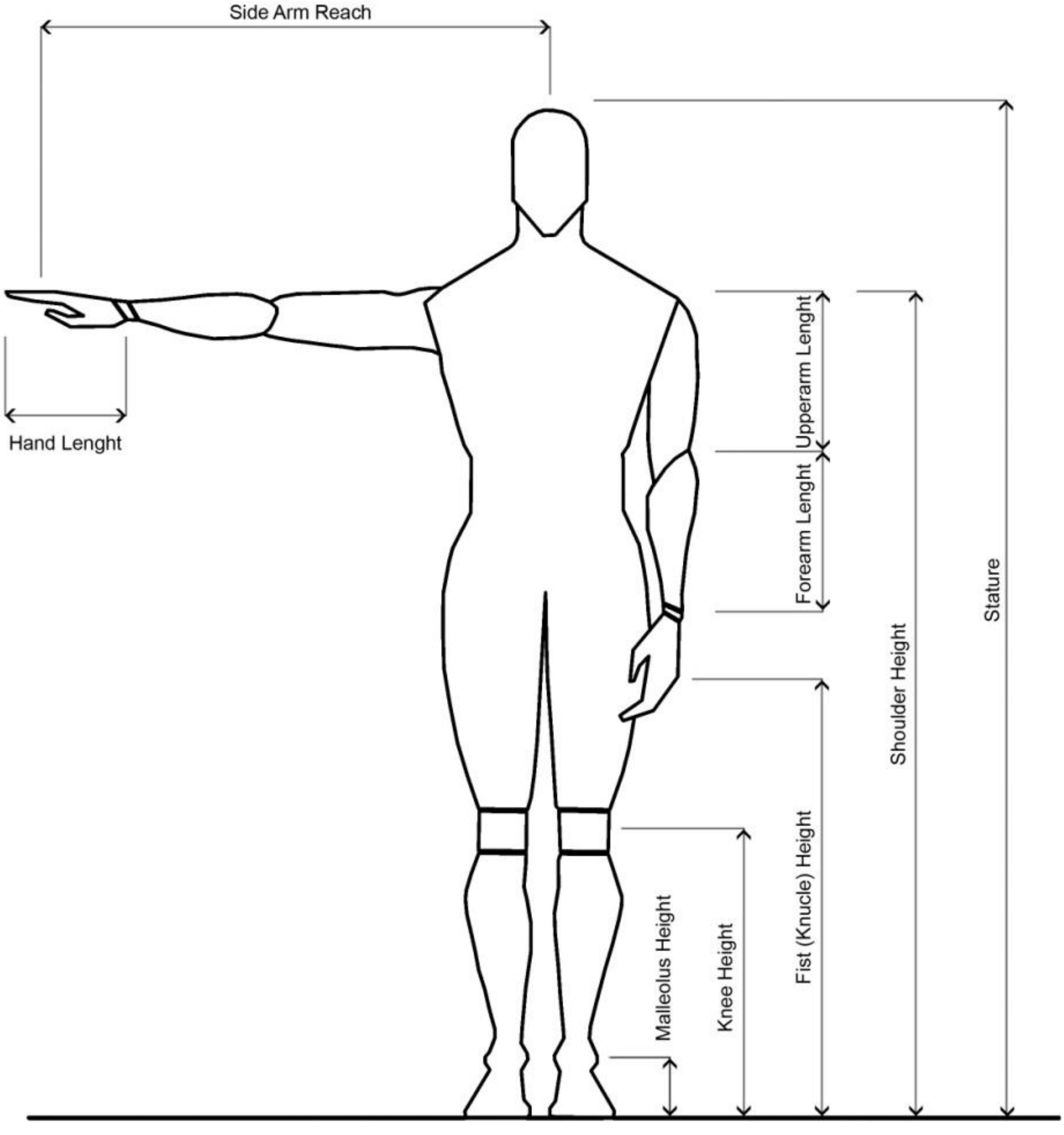

Figure1. Standing Posture Measurements (Drawn by author, adapted from Panero & Zelnik, 1979)

3. Results and discussion

Table 1 shows the descriptive statistics of the obtained measurements of the body dimensions of the participants. Table 2 shows the results of riser height research.

Table 1. Percentile values of the anthropometric measures of participants (dimensions in cm).

	Mean		**5%**		**95%**		**Standard Deviation**	
	Male	Female	Male	Female	Male	Female	Male	**Female**
Stature	177,56	162,30	164,00	152,00	190,00	175,00	7,77	6,36
Shoulder Height	146,50	136,50	136,50	123,00	155,50	141,50	6,23	6,14
Side Arm Reach	91.97	83,12	79,10	74,00	105,90	92,45	6,64	6,11
Knee Height	52,51	47,15	45,00	40,77	59,45	55,45	4,07	4,07
Fist (Knuckle) Height	74,12	69,27	66,97	61,42	79,83	74,38	4,09	4,01
Shoulder Fingertip Length	77,26	69,75	70,38	65,12	84,78	76,28	4,67	5,62
Upper Arm Length	36,29	29,98	31,18	27,92	40,11	35,47	3,16	3,68
Forearm Length	26,96	25,38	21,55	22,77	30,45	27,90	2,37	1,64
Malleolus Height	9,44	8,23	7,00	6,00	12,00	10,45	1,70	1,47
Hand Length	**20,37**	**18,48**	**18,00**	**16,55**	**23,00**	**20,45**	**1,49**	**1,14**

Table 2. The results of riser height research.

Step Height	**15 cm**	**16 cm**	**17 cm**	**18 cm**	**19 cm**	**20 cm**
Percentile	12	26	31	22	7	2

The most significant aim of the design projects is developing design standards that can be suitable for almost the entire target group. In these projects 5%-95% of the parts should be targeted (Pheasant, 1996). In design, 95th percentile values must be determined for clearance and fifth percentile for reach. Also it is accepted that there is a difference between sexes in the society. Especially, given the designs, it is mandatory to determine 5th and 95th percentile values to address all segments of the society. Thus, the 5th percentile value for the women better represents the lower 5th of the population and 95th percentile value for the men better represents the highest 95th of the population. Thus, it is important to evaluate measurement values of the women and men by taking the sexual differences into account (Jurgens et al., 1990). The measures that is used for the redesigning of the outdoor fitness equipment are given in Table 3.

Table 3. The measures that will be used for the redesigning of the outdoor fitness equipment (cm)

	Reach	Clearance
Stature	152,00	**190,00**
Shoulder Height	123,00	**155,50**
Side Arm Reach	74,00	**105,90**
Knee Height	40,77	**59,45**
Fist (Knuckle) Height	61,42	**79,83**
Shoulder Fingertip Length	65,12	**84,78**
Forearm Length	22,77	**30,45**
Malleolus Height	**6,00**	**12,00**

In province of Eskisehir, there are different outdoor fitness equipment such as the FE02 Stepper placed by the municipality. These can be found in different parks and gardens, and widely being used by locals. The anthropometric data obtained from the main supplier of the outdoor fitness equipment company in Eskişehir, Senkron Fitness & Medical Products Manufacturing & Marketing Co., which is used for their designs is shown in Table 4.

Table 4. The anthropometric data used for current fitness equipment designs provided by Senkron Fitness & Medical Products Manufacturing & Marketing Co. in Eskisehir (cm)

Stature	**200,00**
Shoulder Height	**150,00**
Shoulder Breadth	**55,00**
Side Arm Reach	**100,00**
Fist (Knuckle) Height	**85,00**
Knee Height	**60,00**
Shoulder Fingertip Length	**90,00**
Fore Arm Length	**30,00**
Malleolus Height	**15,00**
Riser Height	**32,50**

As seen at the Table 4, the measurements used for the outdoor fitness equipment design are not regarded as the reach and/or the clearance for two different situations. Instead, it is striking to see that there is just one measurement used that is neither reach nor clearance. However, in the relationship between user and product, the type of action decides whether the 5% or 95% portion should be used during the design process. It is conventional to refer to the 5th percentile of female data for reach and 95th percentile of male data for clearance.

When Table 3 and Table 4 are compared within the context of the reach and the clearance, it is apparent that there are significant differences between the measurements that are suggested and the outdoor fitness equipment measures that are currently in use.

As a result of the comparison, it is determined that the outdoor fitness equipment which are in use do not have any anthropometric validity, and therefore rise a risk for public health.

3.1. Re-design of FE02 Stepper

Inadequacies of the sport equipment play an important role in actions that involve failures or injuries (Aydın, 2006). According to Wittenberg (1985), the main reason for inadequacy in sports equipment is the poor design.

The objective of using outdoor fitness equipment is to train certain muscles, so it is closely connected with the human body during exercise. With regard to this situation, the major design problem can be defined as *appropriateness for the user*. A product which is not suitable for its user will not be convenient. In retrospect, the user will not be able to achieve to the intended performance and/or will face the risk of getting injured. The risk of getting injured will bring forth a third problem, namely *safety*. Designing products, which does not hurt its intended user, is the main responsibility of the designers.

After summarising and analysing the anthropometric data, the managers of the fitness equipment producer company, Senkron Fitness & Medical Products Manufacturing & Marketing Co., were informed about the found mismatches and offered to re-design a product of their choice which will also serve as a sample for future projects. The Managers have chosen FE02 Stepper, given as Figure 2, which is an outdoor fitness equipment used to tone lower body while raising heart rate and helping to increase cardiovascular fitness.

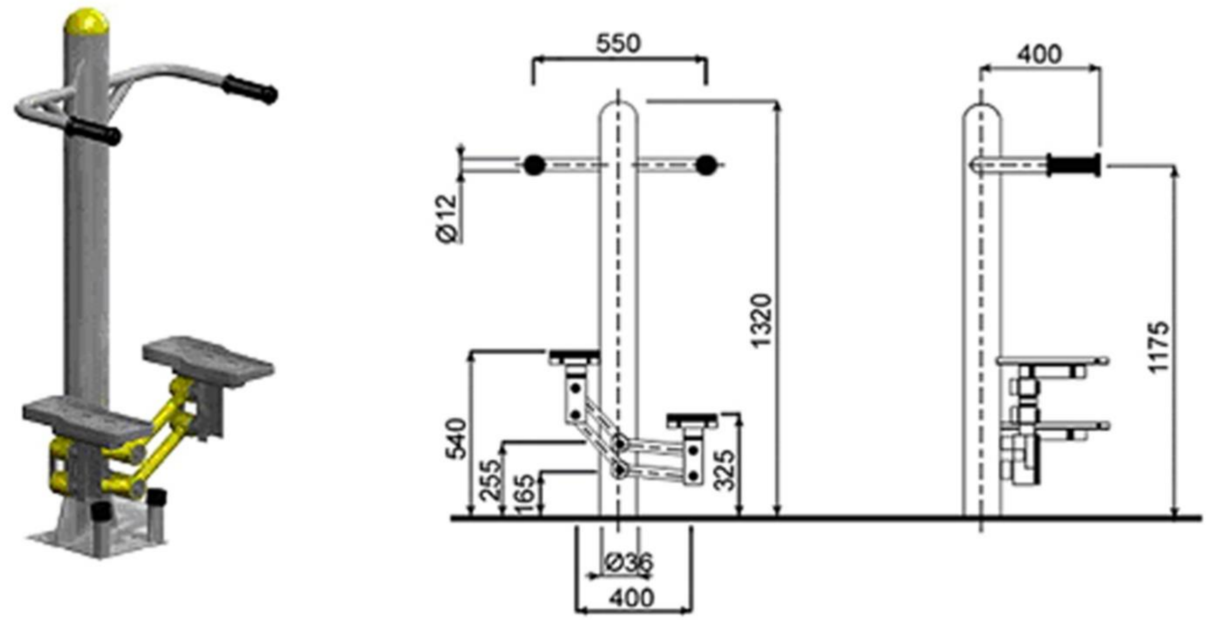

Figure 2. FE02 Stepper

As seen from the Figure 2, for the FE02 Stepper, fist (knuckle) height is 85.50 cm, but according to our research results, fist (knuckle) height should be 79.83 cm. Also FE02's riser height is 32.50 cm. According to Panero and Zelnik (1979), the riser height must be 17 cm. During the collection of anthropometric data of people living in Eskisehir, shoulder breadth has not collected. While re-designing FE02 Stepper for shoulder breadth data of people living in Eskisehir, Pheasant's ratio scaling technique is used. According to this technique; if the parameters of variables x and y are known in a reference population A, but only the parameters of x are known in population B (which is called the ''target population''), then provided that populations A and B are similar (İşeri & Arslan, 2009):

$$Amy/Amx \ =\approx Bmy/Bmx \tag{1}$$

So we accepted Panero and Zelnik's (1979) stature and shoulder breadth data as known population parameters and our stature data as the only known parameter;

$$184.9/52.9 = 190/\ Bmx \tag{2}$$

The shoulder breadth value is found as 53.36 cm.

According to Sakallıoglu et al. (1993) if the design of the sport equipment's dimensions does not comply with the intended population, correct posture couldn't be achieved. Indeed inappropriate postures cause injuries and deformities (Ozer, 1993). Also Axelsson's (1995) research showed that inappropriate postures cause ten times less efficiency than correct postures. Thus, gait motion and walking kinematics were compared with the output motion of the product and it is found that FE02's design is inappropriate for posture and human locomotion since its mechanism causes angled steps and strains at lower extremity. The mismatch between lower extremity biomechanics and FE02's motion arises because of faulty mechanism design.

Figure 3. FE02 Stepper and exercise

During the exercise, when the left and right foot height from the ground are equal, the angle between two leg is 33˚; as seen at the Figure 3, at full pushed down unbend leg becomes as possible as parallel to sagittal plane for balancing the body, and the angle between bended and unbend legs becomes 33˚. Yet, angle of internal rotation in flexion angle is maximum 30˚. As the body pass the limits in order to keep the balance, bended leg makes rotations in knee flexion, ankle inversion and dorsiflexion in addition to hip and knee flexion. While, the unbended leg becomes as possible as parallel to sagittal plane for balancing the body both legs make internal and external rotations which constrains knee tendons and ligaments.

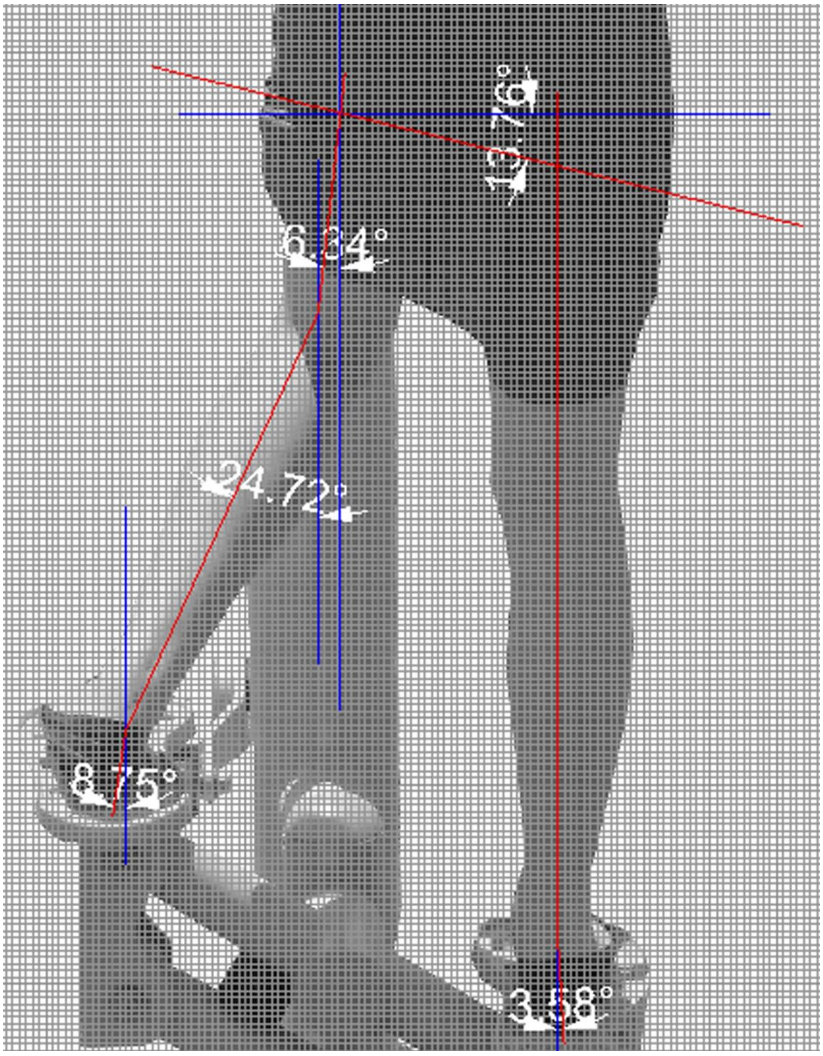

Figure 4. Angles during exercise

According to Panero and Zelnik (1979) limitation of midtarsal joint abduction and adduction angle is 5° and limitation of internal rotation in extension of knee is 20°. Yet, as seen at the Figure 4, the kinematic angles for midtarsal joint adduction is 8.75° and of internal rotation in extension of knee is 24.72°. In this exercise, tensile of knee tendons and ligaments does not cause instant injuries but in long term usage may cause soft tissue damage and pain. As seen at the Figure 5 and Figure 6, since FE02 Stepper forces its users to exceed the biomechanical limitations and shape lower extremity abnormally, it leave its users wide open for injuries. Hence, FE02 Stepper's design is inappropriate for posture and human locomotion as its mechanism causes angled steps and a wrong mechanical and anatomical axes of the lower extremity during exercise. If the users' lateral and medial collateral ligaments are weak, the exercise will increase the degree of pain and may cause meniscus tears. Also hip abductor muscle group hypertrophy could be diagnosed as a result of overuse.

Figure 5. Ankle over-strain

Figure 6. Over rotation, over adduction and over flexion

One of the achievements of designing outdoor fitness equipment should be providing safety. In the context of FE02 stepper's design, for achieving this goal, output motion should be compatible with normal human step-up motion. Although lower extremity is able to do angled motions, the normal step-up motion occurs parallel to the sagittal plane. Therefore, to avoid the safety risks mentioned above, FE02 Stepper's output motion should be straight and doesn't force the lower extremity to make internal and external rotations during knee flexion, ankle inversion and dorsiflexion.

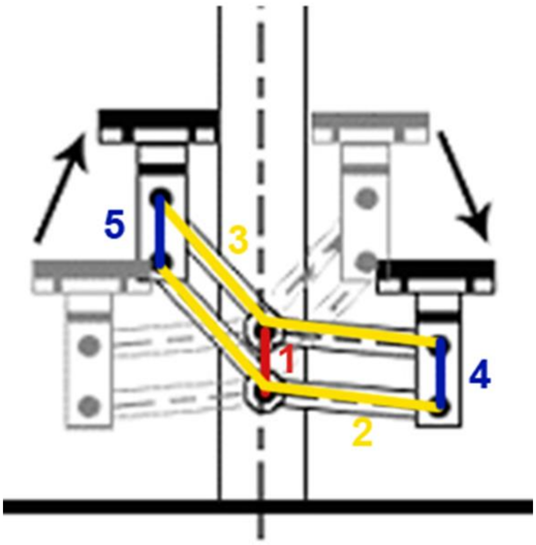

Figure 7. FE02 Stepper's mechanism

FE02 Stepper's mechanism, given as Figure 7, is a parallel motion linkage which is modified for the task. The modification was made at second and 3th links; they were lengthened. One additional link, 5th link, was added for second foot and by this way a five bar mechanism was obtained.

Degree of freedom of FE02 Stepper's mechanism is:

$$M = 3(n-1) - 2xf1 + q \qquad (3)$$

$$M = 3(5-1) - 2x6 + 1 = 1 \qquad (4)$$

In this equation, q represents the additional link which doesn't affect the output motion but it is a necessity for stepper's function.

New mechanism's mobility should be 1 as current mechanism. In addition, new mechanism's links shouldn't be over range the feet alignments and attachment points of links shouldn't be at the same level with feet alignments. Besides that, as simplicity is preferred in machine design and it should be considered that chosen straight line linkage should be modified for both foot.

A mechanism which produces straight line motion by using turning pairs is known as straight line motion mechanism (Phakatkar, 2009).

Straight line motion mechanism is a very common application of coupler curves is the generation of approximate straight lines (Norton, 2004).

Accomplishment of exact rectilinear motion is practically impossible for a four-bar linkage. There are numerous mechanisms which approximately achieve rectilinear motion on a segment. They are mostly mechanisms in which the coupler curve is symmetrical, and the point on the working part (coupler) whose motion is observed lies on the direction normal to the direction of the support and it coincides with its centre line, which is at the same time the centre line of the coupler curve (Bulatovic´ and Dordevic´, 2009).

Many kinematicians such as Watt, Chebyschev, Peaucellier, Kempe, Evans, and Hoeken (as well as others) over a century ago, developed or discovered either approximate or exact straight-line linkages, and their names are associated with those devices to this day (Norton, 2004).

If straight-line linkages are evaluated according to criteria given above; it can be seen that Watt's (Ferguson, 1962) and Chebyshev's (Eckhardt, 1998) mechanisms' links are over range, Evan's (Sclater, 2001) and Robert's (Kempe, 2008) mechanisms' attachment points of links are at the same level with feet alignments. Peaucellier straight-line mechanism's (Pennock, 2007) links are in rage and there is no attachment points of links at feet alignments but it is a more complex linkage, than the four bar; it has eight links. Hoeken's straight-line mechanism is the one that suits the criterions (Bulatovic´ and Dordevic´, 2009; Norton, 2004; Rai et al., 2010). Hoeken's straight-line mechanism and its mirror image could be interlinked for both foot usages, so, as seen at Figure 8, a multi-loop mechanism could be obtained. As both of the mechanisms should be attached at same surface, the grounded link is common, and one more link is needed for keeping motion flow and mobility of 1.

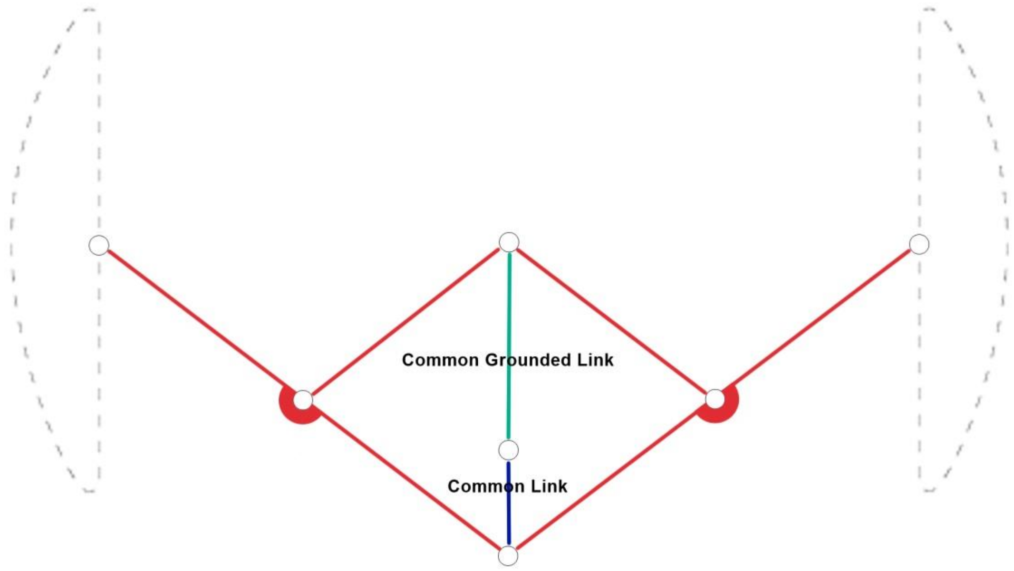

Figure 8. Merging Two Hoeken's Straight Line Linkage

Since accurate portion of straight line should be 17 cm due to riser height, lengths of links should be calculated according to this value and range of motion should be 180˚. According to calculations the lengths of links found as: L1=8.9452, L2=4.0660, L3=11.3848 and L4=5.6924. Also, the trajectory graph of algebraic position analysis of new mechanism can be seen at Figure 9.

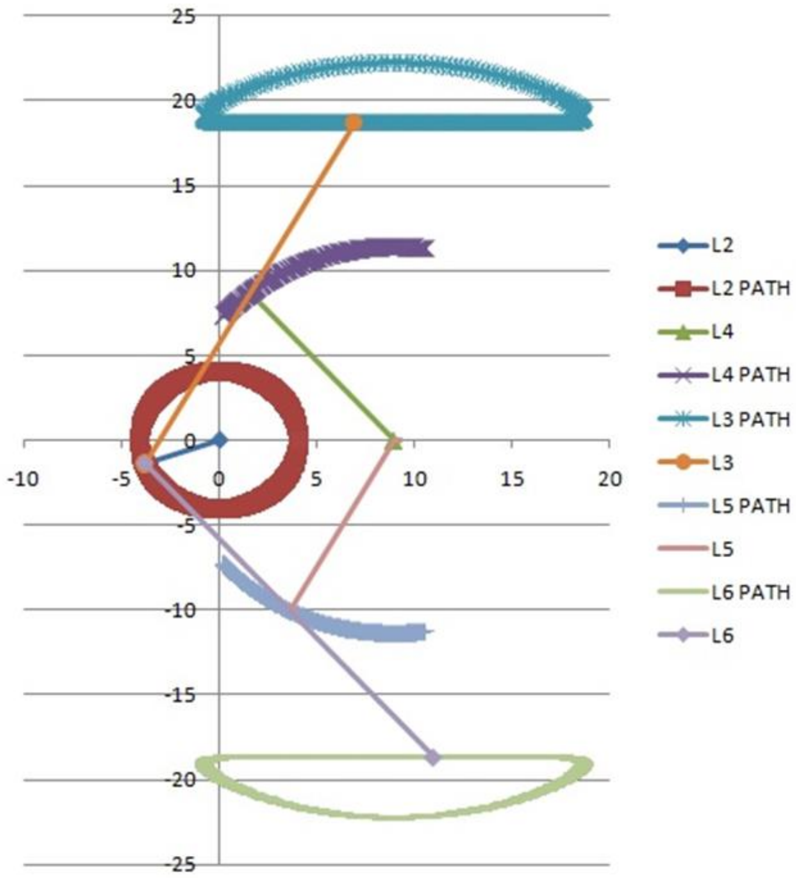

Figure 9. Graph of new mechanism's geometrical trajectory

Once the new mechanism's output motion was approved, the new mechanism and new stepper design modelled by using Rhinoceros Evolution v4.0®. Besides resizing the product corresponding to the anthropometric and biomechanical data, FE02 Stepper's presented other design failures that should be corrected to satisfy the users. In this step of the re-design process, brainstorming and simulation and modelling research were commonly used to add new product features. According to results:

- FE02 Stepper is outdoor fitness equipment so the users of the product should be protected from negative weather conditions. In order to protect them from sunlight and rain, a roof can be added to the design.
- To prevent misuse of the product and inform user about the purpose of the product, a plate user guide should be attached to the product at the eye level.
- FE02 Stepper has a metal body that is coated by cataphoresis treatment and painting for anti-corrosion. Despite these anti-corrosion treatments, FE02 Stepper still needs high cost corrosion maintenance. This high cost could be avoided using of a different material such as PBT (Polibutilen Tereftalat). And also the surfaces which interact with the user's body such as hand folds could be coated with Elastomers, such as rubber or silicone.

The final re-design of the FE02 Stepper and its technical details can be seen at Figure 10 and Figure 11.

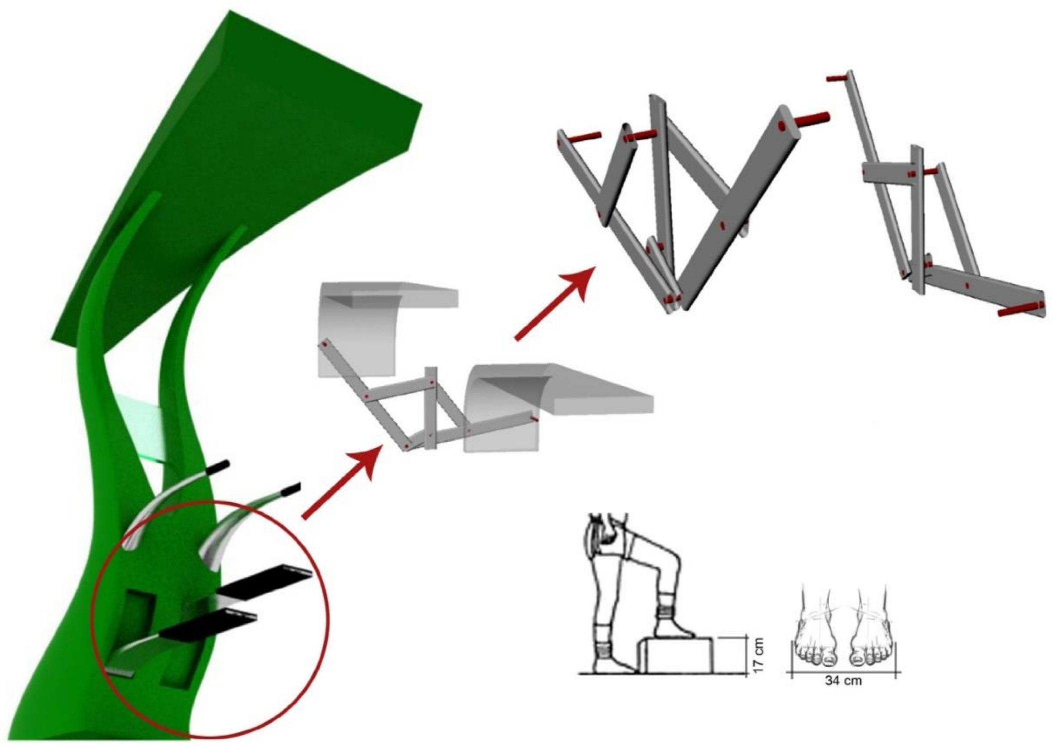

Figure 10. The final design

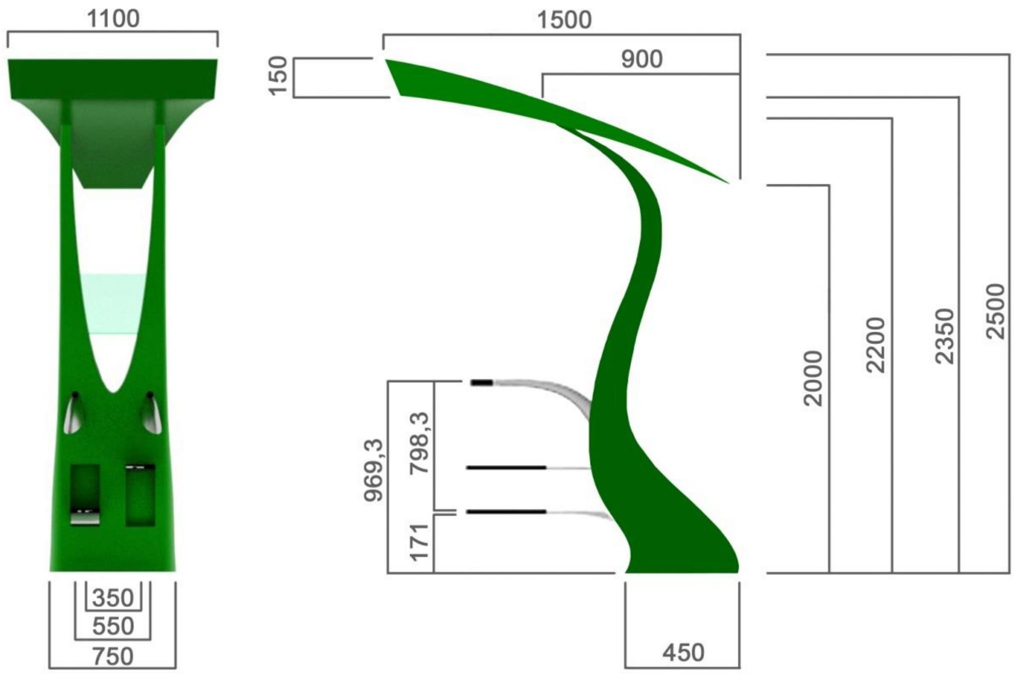

Figure 11. Technical drawing of the designed outdoor fitness equipment

4. Conclusion

The aim of this research is to use ergonomics as a tool to achieve suitable outdoor fitness equipment for Turkish people. It is the first study that has been carried in Turkey and it has been seen that the continuity of this kind of studies are beneficial for the sake of designing safe products and public health. Hence, this study can be a reference of how to use anthropometric and biomechanical data in designing injury risk free outdoor fitness equipment.

Since, outdoor fitness equipment which are synchronous with their user's interaction considering into this study, key points of the user's movement and anthropometric data accepted as the main factors. Therefore, in this study, outdoor fitness equipment, FE02 was corrected in the light of anthropometrical, biomechanical and mechanical context.

A total of ten anthropometric dimensions collected from 100 adults (50 male and 50 female), are listed in tables with mean, standard deviation and selected percentile values. The differences between anthropometric dimensions that are summarised and analysed in the domain of research and the anthropometric data that is used for current outdoor fitness equipment's design are compared and discussed. The comparison showed that the difference between them is significant and the outdoor fitness equipment that are currently in use are not ergonomic and safe at all as they do not fit to their users. Besides being incompatible in the context of anthropometrics, it is found that the product is also inappropriate biomechanically and has high injury risks.

Not only FE02 stepper but almost all the outdoor fitness equipment that are currently in use Turkey might be designed without taking appropriate anthropometric and biomechanical data into consideration. Therefore, to prevent injuries and to preserve public health all the outdoor fitness equipment that are currently in use should be evaluated and re-designed immediately if it is necessary.

Conflict of Interest

No conflict of interest was declared by the authors.

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