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Development of a Structured Protocol to Determine Multimedia Screen Position on CV Equipment

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Abstract. Integrated media screens on cardiovascular (CV) exercise equipment have the potential to increase both adherence and effort of exercising participants. However, watching and interacting with media screens is challenging on CV equipment due to conflicting ergonomic needs of ‘best’ placement for viewing and touching activities. Scientific evaluation is lacking on what is now considered a ‘must have’ feature on modern exercise equipment. The purpose of this study was to develop a protocol for assessing the ergonomics of fixed screens on CV equipment. Fixed screen position preference, based on users’ touching and viewing experience, was compared between 3 methods based on 1 -previous literature including EN ISO 11064-4:2004, 2 - by the user during testing using a free-moving screen, and 3 –the sponsoring company’s settings. The study investigated screen height, angle and distance running on a treadmill and cycling on a stationary upright cycle. Seven recreationally active adults, (mean ± SD; 28 ± 6yrs) were selected based on a representative range of eye heights (1st, 29th, 50th, 82nd and 97th).Each subject completed 6 bouts of 5-min exercise on each respective cardiovascular device comprising the 3 different treadmill or bike screen positions and 2 different user operating conditions. Participants interacted with games on-screen during or simply watched TV whilst wearing headphones. In the bike study, seat-height was based on Lemond’s coefficient (SICI, 2010) and Participants adopted three generic postural positions (normal, city and chrono). The order of conditions was counterbalanced within the subject group. In both the treadmill and bike study, 50th percentile Participants preferred the user defined screen positions, but there was little objection to the manufacturer’s fixed position which was preferred to the anthropometric devised position. The anthropometric devised screen position was deemed ‘unsuitable’ highlighting the lack of understanding in ergonomics for exercise specific requirements. Expert opinion from the manufacturer was within the resulting recommended screen heights, distances and angles recorded from this study. A novel ergonomic assessment method was successfully developed to best understand user preference of fixed touch-screen position when exercising on a treadmill and upright bike with the aim of ‘best’ placing a fixed touch-screen position for 50th percentile eye-height user group. Future studies can employ the principles used in this study and develop this field of ergonomics with the ultimate aim of improving user experience when using exercise equipment.

Keywords: ergonomics, exercise, screen, equipment, media, interaction.

1. Introduction

The advent of interactive touch screen displays coupled with internet connectivity on cardiovascular (CV) exercise equipment has led to an increased consumer demand for multimedia information to be available during exercise. New systems now display speed, time, distance, calories, pulse rate, speed control, incline, and workouts guide interactively, whilst also allowing the user to view or listen to popular media or to browse the internet. Warburton *et al.* (2007) suggest there was a significant increase in attendance to interactive video exercise sessions and a measurable physical improvement was observed when compared with traditional exercise sessions in male college students. Watching and interacting with popular media, such as 35Hz video streaming, is challenging on CV equipment due to its conflicting needs of ‘best’ placement of viewing and touching elements and the possibility of blurred images whilst moving during exercise. Literature examining office working environments indicate that an ‘optimum’ screen placement for touching and viewing are not the same (BS EN ISO 9241-5:1999, BS EN ISO 11064-4:2004 and BS EN ISO 14738:2008), therefore a compromised placement is needed. This study details the development of a structured protocol to provide a process for determining the placement of a fixed touch screen on CV equipment. Positioning was based on previous literature, user tests and company design experience. The study investigated screen height, angle and distance from the user whilst running on a treadmill and whilst cycling on a stationary upright cycle.

There is a dearth of published information detailing ergonomic best practice for CV screen placement; therefore, the guiding principles outlined in British Standard workstation design were used as the basis from which to develop a novel touch screen placement protocol. British Standards, EN ISO 9241-5:1999, EN ISO 11064-4:2004 and BS EN ISO 14738:2008, provide ergonomic guiding principles for workstation design intended for use by product and workstation designers and implementers. The arrangement of workstation displays depend on several factors including eye height influenced by posture and body dimensions, visual extent of the displayed characters, frequency of visual scanning, and the display dimensions (EN ISO 11064-4:2004). The ergonomic considerations of display placement must consider viewing distance, display angle, height and depth of the console and hand-reach envelope respectively (EN ISO 11064-4:2004). A summary of relevant research literature is provided in Table 1. For all height allowances BS EN ISO 14738:2008 recommends an additional 30mm when wearing shoes, 130mm for shoes and foot movements and 130mm for shoes and possibility to cross legs or for seat forward sloping adjustment respectively. The recommended field of vision for frequent handling and observation without requiring head and body movement is 30° starting 20° below horizontal with an additional 30° where downward head movement is permitted (EN ISO 9241-5:1999, EN ISO 11064-4:2004 and BS EN ISO 14738:2008). When standing the total field of vision extends only 45° below horizontal, but the preferred field remains at 30° starting at 20° below horizontal (EN ISO 9241-5:1999). Whilst the extent of the visual field is approximately ±35° according to EN ISO 11064-4:2004, only 1-2° of these are for sharp vision. The recommendations detailed are based upon the following reference posture when seated (EN ISO 9241-5:1999):

- the thighs positioned in a horizontal position and the lower legs vertical
- the upper arms hanging vertically with the forearms horizontal
- no deviation or extension of the wrists
- an erect spine
- the sole of the foot making an angle of 90° with the lower leg
- no twisting of the upper torso
- the line-of-sight between horizontal and 60° below the horizontal

Table 1 Guidelines in literature for screen placement

Parameter	Guideline for screen placement	Reference
Screen height	Touch distance 50-100mm below user’s elbow height	Pheasant (2006)
	Max: 1554mm and Min: 1315mm touching distance from floor when standing	BS EN ISO 14738:2008
Screen angle	0° perpendicular from eye-screen is ‘optimum’ but can be up to 40° either side of 0°	EN ISO 9241-5:1999; EN ISO 11064-4:2004; Pheasant (2006); Dreyfuss (2002)
	‘Optimum’ line-of-sight: 35° below horizontal;	EN ISO 9241-5:1999; EN ISO 11064-4:2004; Sommerich *et al.* (1998)
	‘Mean’ line-of-sight: 18° below horizontal Min: 10° Max: 30° line-of-sight below horizontal	Pheasant (2006)
	‘Mean’ line-of-sight: 22.5° below horizontal	Dreyfuss (2002)
Screen distance (horizontal from eye)	290mm comfortable touch distance; 415mm maximal touch distance	BS EN ISO 14738:2008
	491mm ‘optimum’ viewing distance Max: 614mm, Min: 368mm ±123mm adjustability in viewing distance	EN ISO 9241-5:1999
	Min: 410mm viewing distance; Min. touch distance dependent on 5th percentile	EN ISO 11064-4:2004

Ankrum and Nemeth (2000) identified that a 43° head/neck angle from vertical is deemed comfortable.

However, it is recognised that personal preference also plays a role and different people of similar size may feel comfortable in different postures for a particular task or activity (Garneau and Parkinson, 2007).

Ergonomics of cycling has received notable attention in recent years with the introduction of a 'bike fitting' industry. One of the more established organizations, Serotta International Cycling Institute (SICI), have developed a series of guidelines of lower body angles to improve comfort, safety and power whilst riding a road bike. Comfortable bike seat height is based on the an extended knee angle of between 25°-35° when the crank is parallel to the seat tube at the bottom of the stroke. There is limited research on the effects of upper body position on comfort, performance and safety, and as a result is a subjective judgement by the bike fitter taking into account an individual's flexibility, core strength, injuries, type of riding, years riding, level of ability and goals respectively. A pelvic angle of ~45° relative to the ground is typical, while a back to arm angle of 90° and an elbow angle of 15-30° is desirable.

2. Methods

Fixed screen position preference, based on users' touching and viewing experience, was compared between 3 distinct set-up methods.

The first position, Anthropometric devised (AScP), was based on current recommendations in literature (Pheasant, 2006 and Sanders, 1993) using the principles outlined in EN ISO 11064-4:2004 based on 50th percentile user anthropometrics, considering the complete range of male and female heights. According to AdultData (1999) mean standing eye height for 16-65 UK males and females was 1573mm, with 5th percentile and 95th percentile equating to 1436mm and 1729mm respectively. This data was based on The PeopleSize (1998) dataset which was validated against two 'gold standard' population surveys, the National Health and Nutrition Examination Survey (NHANES) conducted by the US Government and the Health Survey for England conducted by the UK Government.

The second, (EScP), was based on the sponsoring company's in-house ergonomic expertise and experience gained from previous user trials. The third, User defined (UScP), was decided by the user during testing using a free-moving screen.

2.1. Participants

Seven (five female) recreationally active adults, (mean ± SD; 28 ± 6yrs) provided informed consent to take part in an ergonomic analysis task to determine best placement of CV equipment displays. Participants of varying eye heights were chosen, however, focus was given to the 3 participants in the 50th percentile eye-height user group. It was expected that the 50th percentile user group (50th %tile) would find the positions more comfortable than the 1st-99th percentile user group (1st-99th %tile), as AScP and EScP were based on this group.

Table 2: Detailed anthropometric data of each subject

	50%tile eye height			1 %tile	29 %tile	82 %tile	97 %tile
Subject	1	2	3	4	5	6	7
Gender	Female	Female	Female	Female	Female	Male	Male
Age (yrs)	28	41	23	25	26	28	26
Height (mm)	1673	1680	1674	1540	1636	1780	1860
Weight (kg)	55.0	57.0	69.2	54.0	52.0	63.0	81.0
Eye height (mm)	1565	1577	1578	1382	1520	1667	1742
Max. reach length (mm)	690	710	695	640	650	725	745
Comfortable reach (mm)	520	560	540	500	570	700	620
Dominant hand	Right	Right	Right	Right	Left	Right	Left

2.2. Development of an Anthropometric devised screen position

A hypothesized anthropometric 'optimum' treadmill position was devised using literature recommendations and 50th percentile anthropometric measures by Pheasant (2006), based on knowledge of upright workstation design. Pheasant's (2006) and Sanders (1993) recommendations were:

- Viewing angle was 18° below the horizontal plane
- Screen angle was to be perpendicular with the line-of-sight, equating to 72° from vertical
- Screen distance from the eye was 650mm
- Screen height from belt was 1373 mm

Few studies have investigated display placement when the body is angled and in-motion as in an upright bike; therefore ACsP was based on observations from the treadmill study as well as Pheasant's (2006) recommendations with a focus on the 50th percentile user. Bike posture was based on a 30° back angle determined as the average back angle each of the 7 Participants exhibited during initial observations. Horizontal distance of the screen from the crank was based on touching distance rather than viewing distance and was the mean of the treadmill trial; 425mm from the acromion to screen centre. ACsP screen placement was:

- Screen height from crank centre of 958mm
- Screen angle of 45°
- Distance from crank centre of 510mm
- Seat height from crank centre of 690mm (SICI, 2010)

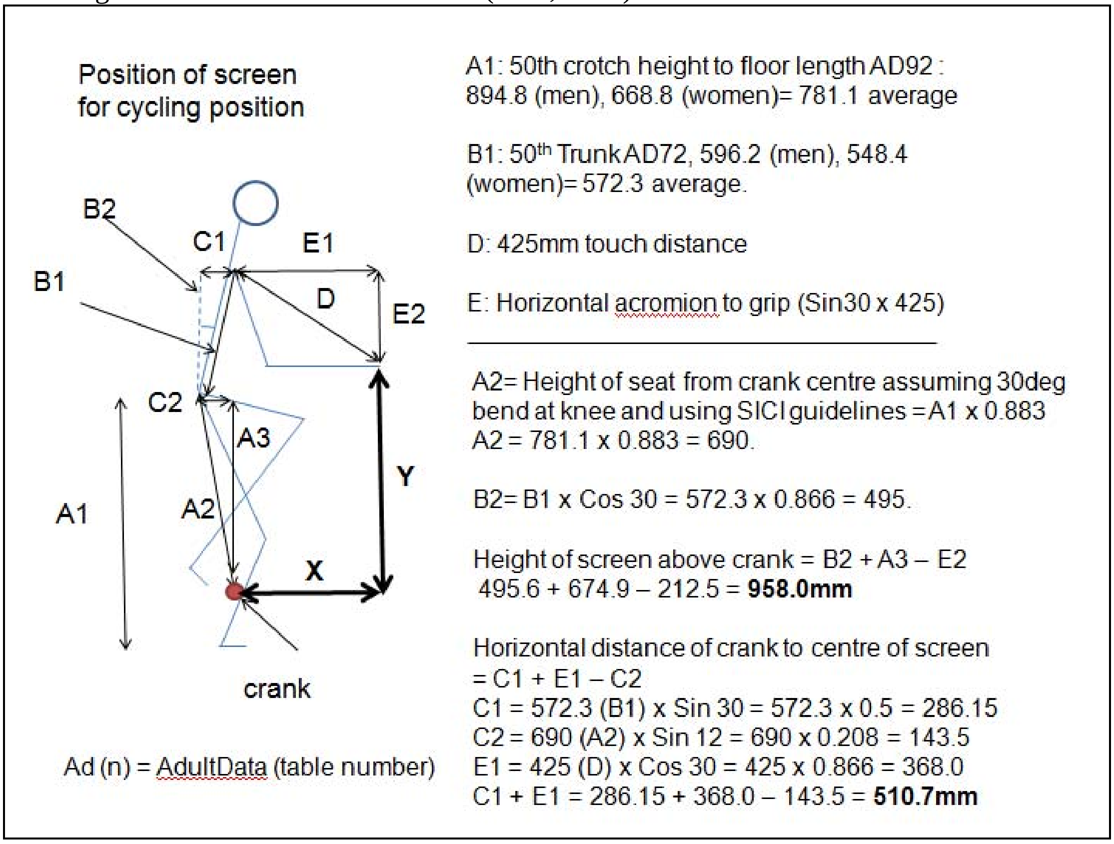

Figure 1: Anthropometric screen height (mm) and distance (mm) from crank in the bike trial

2.3. Development of screen position based on designer experience

The development of Technogym screen position derived from the specific know-how accumulated by the Techno Gym Scientific Research Dept. over the last 25 years successfully applying biomechanical knowledge to fitness equipment design. As described above, there is little research evaluating the visual ergonomics of the body in-motion on a fitness machine: in fact, most of published studies refer to the static position of the person at work, typically to identify the optimal layout of the desk or workstation.

For these reasons, it is clear that the most important issue to be addressed in the assessment of the visual ergonomic of a fitness machine whilst moving is to understand the position in the space of the eyes and the dislocation, due to movements, of the body during the exercise.

Although the treadmill and bike are very different pieces of exercise equipment, with of course a different interaction of the user during exercise, the process to determine the correct position of the screen is much the same.

Based on the amount of data collected in the past years, Technogym Scientific Research Dept. stated that the average height best representing the "typical user" was 170cm.

In finding the position of the display on the treadmill, the location of the eyes was set 10 cm below the top of the head in a still standing situation (based on anthropometrical data and on a series of experiments conducted at the following speed: 3km/h, 5km/h, 7km/h, 9km/h, 11km/h). Moreover, the average distance from the handle bar was evaluated to estimate the horizontal displacement during the exercise at the above mentioned speeds (average 40cm ±5cm). Having fixed these points, and based on the data from Dreyfuss et al, it was estimated that the optimal visual area (cone of vision) should be set between 15° and 30° below. At 22.5° it has been defined the ideal diagonal of vision within the visual area.

The goal of this process was to align the display position with the identified diagonal of vision as mentioned above, resulting quotes as follow:

- Screen angle was to be perpendicular with the line-of-sight, equating to 62°.
- Screen distance from the eye was 650mm.
- Screen height from belt was 1239mm

In finding the position of the display on the bike, it has to be considered that Technogym equipment present three different user's positons: Normal, City and Chrono (see Figure 2). From internal studies we found that the City position was the most used, it was therefore considered as the benchmark for the evaluation of ergonomics.

As for the treadmill, the position of the eye was set and the display was fixed as follow:

- Screen height from crank center of 960mm
- Screen angle of 45°
- Distance from crank center of 583mm

2.4. User-defined screen position

After experiencing both the AScP and EScP, each participant moved the screen to a preferred touching and viewing distance and angle. The subject was asked: "*please move the screen to a position where it would be most comfortable for touching and viewing*".

2.5. Exercise Trial

On two separate occasions (treadmill and upright bike study) each subject was asked to enter the laboratory rested, after having previously refrained from strenuous activity 24hrs prior. Each subject completed 6 bouts of 5-min exercise on each respective cardiovascular device. The 6 bouts of exercise comprised of Participants being exposed to 3 different treadmill or bike screen positions (AScP, EScP and UScP) and 2 different user operating conditions (HI and LI). Participants played matched-pair card games on-screen during HI and simply watched TV whilst wearing headphones during LI. Intensities (treadmill speed and bike cadence) were self selected during initial familiarisation and remained constant throughout the study. Participants were asked to "*please select a speed with which you would be able comfortably operate the screen while exercising*". In the bike study, seat-height was dictated by the investigator based on Lemond's coefficient (SICI, 2010) and Participants were asked to adopt three generic postural positions (normal, city and chrono) as shown in Figure 2. Participants rated screen position in each of the three postural positions (normal, chrono and city), before selecting an UScP that was most comfortable for the City position, but adequate for the Chrono and Normal positions. Three minutes of seated rest was provided between bouts. The order of conditions and positions were counterbalanced within the subject group.

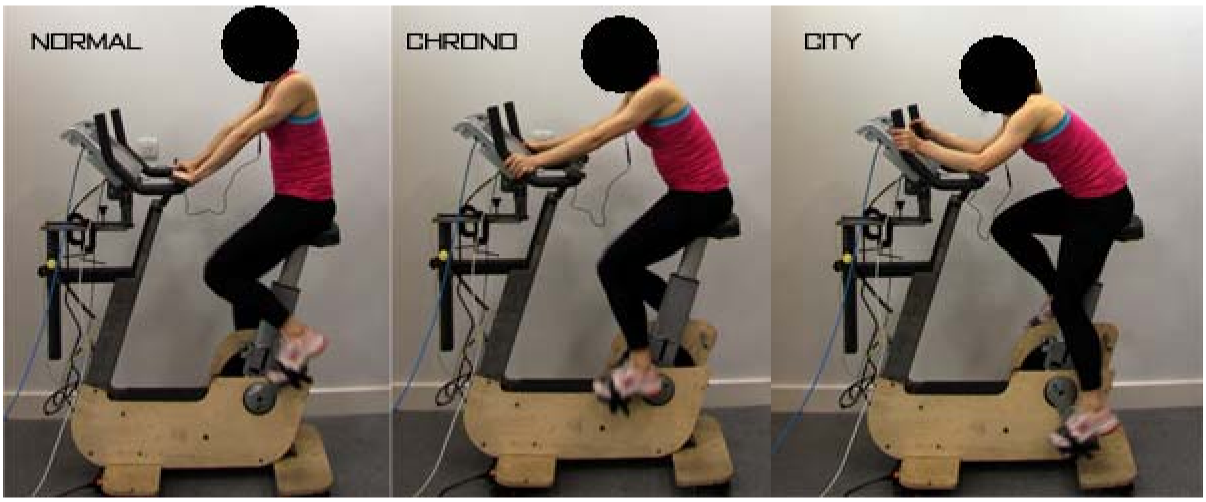

Figure 2: Bike postural positions during trial: normal, chrono and city

While continuing to exercise, Participants responded to the statements relating to touch and viewing screen position preference, detailed in Table 3. Participants provided comments on possible screen movement to provide a better experience (i.e. up or down, back or forward), as well as button dimensions and position on-screen. Finally, Participants commented on wrist, eye and back discomfort and feelings of motion sickness.

During 5-min of exercise, side-view photographic images were collected to determine body postural position and relation to screen. Six measures were recorded: eye to screen distance (mm), angle of the eye to screen (°), reach distance measured from acromion to screen centre (mm), tragus to eye angle (°), horizontal eye-line angle (°) and C7 to tragus angle (°) denoting head tilt.

Table 3: Questions used to discern user preference of screen position

TOUCH	**Please respond using the following rating scale**
The screen is at a suitable height for me to touch? The screen is at a suitable distance for me to touch? The screen is at a suitable angle for me to touch?	1. Agree strongly 2. Agree slightly 3. Neither agree or disagree 4. Disagree slightly 5. Disagree strongly
VIEW	
The screen is at a suitable height for me to see? The screen is at a suitable distance for me to see? The screen is at a suitable angle for me to see?	
OVERALL	
The screen is in an overall suitable position for me to comfortably touch and see it while exercising? The whole exercise equipment was comfortable to use?	

3. Results

3.1. Treadmill test

Results from the treadmill study were summarized in two exclusive user groups 50th %tile only (Table 5) and 1st-99th %tile (Table 6).

Table 5: Screen positions used in the treadmill study of the mean design group

	AScP	**EScP**	**UScP**			**UScP**
			1	**2**	**3**	**Mean**
Screen height from belt (mm)	1373	1239	1390	1164	1264	**1273**
Screen angle (°)	72.0	62.0	80.6	51.0	62.0	**64.5**

Two of the three 50th %tile Participants preferred a higher screen position than EScP, but all preferred a lower position than AScP. Subject 2 preferred a steeper screen angle, subject 3 the same screen angle, and subject 4 preferred a shallower screen angle than EScP. Participants 2 and 3 preferred a shallower screen angle than AScP, but subject 3 a steeper angle. Mean screen height and angle across the 50th%tile group when screen position was self-selected was 1273mm and 64.5° respectively.

Table 6: Screen positions used in the treadmill study of the range group

	AScP	**EScP**	**UScP**				**UScP**
			4	**5**	**6**	**7**	**Mean**
Screen height from belt (mm)	1373	1239	1280	1270	1280	1290	**1280**
Screen angle (degrees)	72.0	62.0	67.5	73.5	57.1	66.8	**66.2**

Similarly, higher and steeper angled screen positions were preferred among 1st-99th%tile user group than EScP. All preferred a lower screen angle than AScP, and only subject 5 preferred a steeper screen angle. Mean screen height and angle across the 1st-99th%tile group when screen position was self-selected was 1280mm and 66.2° respectively. Mean screen height and angle across the complete dataset including 50th%tile and 1st-99th%tile user groups was 1277mm and 65.5°.

There were 5 reported cases of feelings of slight motion sickness. This occurred in Participants 2, 5 and 6 during the high-activity AScP; citing it was too high causing blurry vision. Subject 1 also experienced it in the EScP and UScP trials during high interaction activity.

Subjective responses to questions in Table 3, suggested screen positions were suitable for HI and LI activities. Results, shown in Table 7, suggest UScP was slightly more preferred than EScP; as denoted by a higher number of "strongly agrees" and an overall rating closer to 1 for the 50th%tile user group.

Table 7: Mean 50th%tile responses to the overall experience and to high- and low-interaction activities

	Overall mean				**High activity mean**		**Low activity mean**	
	Total no. 1's	Both activities	High activity	Low activity	Touch rating	View rating	Touch rating	View rating
AScP	25	1.31	1.28	1.33	1.56	1.00	1.44	1.22
EScP	30	1.17	1.17	1.17	1.33	1.00	1.22	1.11
UScP	32	1.11	1.11	1.11	1.22	1.00	1.11	1.11

Eye-screen (viewing) distance is further when performing LI activities compared to HI activities, which in turn reduces viewing angle. Mean increase in viewing distance when the screen position was self-selected (UScP) for Participants 2, 3 and 4 was 56mm (15%), 39mm (9%) and 111mm (22%) respectively. Consequently, mean viewing angle was reduced for subject 2, 3 and 4 by 1° (8%), 1° (6%) and 3° (22%) respectively. UScP viewing distance ranged from 340-630mm. Reach distance (UScP) again increased when moving from HI to LI tasks. Mean increase in reach distance for Participants 2, 3 and 4 was 54mm (3%), 48mm (10%), and 139mm (25%) respectively. Mean UScP reach distance was 400-550mm during HI activities and 450-700mm during LI activities. Although intra- eye-centre to screen-centre distances were not similar, inter- eye-centre to screen-centre distances were very similar between the 3 screen positions. AScP viewing angles tended towards 15-20° for each individual, EScP between 25-35° (for Participants 2 and 3; between 5-10° for subject 4); however UScP was unique for each individual ranging from 10-35°. No comparable tragus to eye and horizontal eye-line angles were recorded between Participants ranging between 5-20° and 0-10° respectively. Head-neck (C7 to tragus) angle, indicating the potential for neck strain, tended to be similar between screen positions of each subject, but not between Participants ranging between 20-45°.

For 1st-99th%tile user group AScP position was deemed unsuitable during HI and LI activities as denoted by multiple "slightly disagree" and "strongly disagree" comments. However, all Participants indicated that they "strongly agree" and "slightly agree" with the positioning of EScP and UScP. These two screen positions were also more suitable to Participants at the extremes of height. The 1st-99th%tile group preferred a higher screen position with a steeper angle. In this grouping, viewing distances were similar between Participants in the all 3 screen positions. Participants preferred a viewing distance close to 400mm and 500mm distance for HI and LI activities respectively. The same similarities were not recorded for viewing angle, ranging between 5°-35° during HI and LI activities respectively for all 3 screen positions. Head-tilt and head-neck angles were also specific to the individual test subject. Preferred reach distance was different between individuals but similar between HI and LI activities.

Figure 2: Movement of 50th%tile subject from high- (white line) to low-interaction (black line) activity

3.2. Bike test

Results from the bike study were summarized in two exclusive user groups 50th %tile only (Table 8) and 1st-99th %tile (Table 9).

Table 8: Screen positions used in the bike study of the mean design group

	AScP	EScP	UScP			UScP
			1	2	3	**Mean**
Seat height from crank (mm)	690	-	706	720	715	**714**
Screen height from crank (mm)	970	960	980	920	960	**953**
Screen distance from crank (mm)	515	583	610	531	583	**575**
Screen angle (°)	45	45	48	55	48	**50.4**

In the 50th%tile group, subject 1 preferred a slightly higher screen position than EScP and AScP, subject 3 the similar screen height, whereas subject 2 preferred a lower screen position. All Participants in the 50th%tile group preferred a steeper screen angle than AScP and EScP. Subject 1 preferred a screen position further away than AScP and EScP, subject 3 the same screen position as EScP, whereas subject 2 preferred a closer screen position than EScP but further away than AScP. Mean UScP screen height, distance and angle across the 50th%tile group were 953mm, 575mm and 50.4° respectively.

Table 9: Screen positions used in the bike study of the range group

	AScP	EScP	UScP				UScP
			4	5	6	7	**Mean**
Seat height from crank (mm)	690	-	618	600	730	767	**679**
Screen height from crank (mm)	970	960	960	1125	980	980	**1011**
Screen distance from crank (mm)	515	583	563	610	652	563	**597**
Screen angle (°)	45	45	45	55	41	45	**46.5**

In the 1st-99th%tile group, Participants 5, 6 and 7 preferred a higher screen position than AScP, but subject 4 preferred it lower. All Participants preferred the screen closer than AScP. Subject 5 preferred a steeper screen angle, subject 6 a shallower screen angle but Participants 4 and 7 preferred the same screen angle as AScP. Participants 5, 6 and 7 preferred a higher screen position than EScP, subject 5 preferred a steeper screen angle, subject 6 a shallower screen angle but Participants 4 and 7 preferred the same screen angle as EScP. Participants 4 and 7 preferred the screen closer than EScP, but 5 and 6 preferred it further away. Mean seat height, screen height, screen distance and angle across the 1^{st}-99^{th}%tile group when screen position was self-selected was 679mm, 1011mm, 597mm and 46.5° respectively. Mean screen height, distance and angle across the 50^{th}%tile and 1^{st}-99^{th}%tile user groups were 986mm, 587mm and 48.2° respectively. There were no feelings of motion sickness during this study.

Mean responses (Table 10) of the 50^{th}%tile group indicate that the UScP received the most "strongly agree" responses and was rated 1 ("strongly agree") in all of the tasks compared to the other screen positions. The second best position was the EScP position; receiving more "strongly agree" responses and with an average response closer to 1 in all the tasks than AScP.

Table 10: Mean responses to the overall experience and to high- and low-interaction activities

		Overall interaction mean			**High act. mean**		**Low act. mean**	
	Total no. 1's	Both activities	High activity	Low activity	Touch rating	View rating	Touch rating	View rating
AScP	19	1.56	1.50	1.61	1.56	1.44	1.67	1.56
EScP	29	1.25	1.22	1.28	1.00	1.44	1.00	1.56
UScP	36	1.00	1.00	1.00	1.00	1.00	1.00	1.00

Preferred viewing distance ranged between 430-530mm, viewing angle between 5-20° and reach distance between 500-580mm respectively. Similar viewing angles were recorded between screen positions which may suggest that Participants subtlety adjusted their postural position to compensate for the change in screen position. There were few similarities in postural positional parameters across the whole user group aside from Participants' back angle tending towards 30° and neck (C7 to tragus) angle towards 60°. Tragus to eye angles and horizontal eye-line angle ranged from -15 to -2.5° and -12° to -26° respectively.

Subjective results for the 50^{th}%tile group for all postural and screen positions are shown in the Table 11. Participants preferred UScP in all postural positions, but preferred EScP more in the Chrono position and AScP more in the Normal position.

Overall, AScP was the most undesirable screen position of the three in both the treadmill and bike studies. The lack of exercise equipment specific literature meant traditional office ergonomic recommendations were used. A comparison of literature and recorded values are shown in Table 12. Viewing distances were generally shorter, viewing angles at the lower range and reach distances the same. Overall recommendations for exercise tasks like those tested were viewing distances, viewing angle and reach distances of 350-550mm, 10-30° and 400-600mm respectively, as detailed in Table 14.

Table 11: Subjective responses of 50^{th}%tile only user to 3 postural positions.

	Normal	**City**	**Chrono**
No. 1's - strongly agree			
AScP	13	11	9
EScP	8	15	13
UScP	15	18	14
No. 2's - slightly agree			
AScP	4	6	3
EScP	5	2	3
UScP	3	0	4
No. 3's - neither agree not disagree			
AScP	1	1	5
EScP	2	1	2
UScP	0	0	0
No. 4's - slightly disagree			
AScP	0	0	1
EScP	3	0	0
UScP	0	0	0
No. 5's - strongly disagree			
AScP	0	0	0
EScP	0	0	0
UScP	0	0	0

Table 12: Distances (mm) and angles (°) of screen position described in literature compared to mean average recorded in the 50th%tile group. Literature source: A - Pheasant (2006), B - BS EN 894-4, Kodak (2004), Adult data (1999), C - Ankrum and Nemeth (2000), D - SICI (2007).

		Treadmill - high activity			Treadmill - low activity			Bike		
	Literature	**A**	**E**	**U**	**A**	**E**	**U**	**A**	**E**	**U**
A: Viewing distance - (mm)	500-700	425	447	436	503	512	500	424	468	475
A: Viewing angle - (°)	10-30	12.7	22.4	23.9	11.4	19.9	21.5	14.2	12.0	10.6
B: Reach distance - (mm)	370-600	493	481	488	585	563	556	489	530	537
C: Standing C7 to tragus angle - (°)	41	36.3	32.6	33.8	31.2	34.5	33.8			
C: Seated C7 to tragus angle - (°)	43							58.7	56.3	57.3
D: Back angle to tragus - (°)	45							31.1	30.7	31.1

Table 13: Recommended screen height, distance and angle ranges of screen position

	EScP		**Recommended**	
	Treadmill	Bike	Treadmill	Bike
Screen height from belt (mm)	1239		1220-1280	
Screen angle (°)	62		55-70	
Screen height from crank (mm)		960		920-980
Screen distance from crank (mm)		583		550-600
Screen angle (°)		45		40-55

4. Discussion

Screen positioning in exercise equipment must consider user anthropometrics, kinematics and natural postural limitations during the design process. Much literature and International Standard guidelines exist to aid the workstation design process but few address exercise equipment. In this study, a structured development process was employed to determine ‘best’ fixed screen placement on a treadmill and upright bike. Three design approaches were considered for a holistic methodology; user anthropometrics, manufacture experience and self-selection during use. It is hoped that the process outlined will provide a structure from which future exercise equipment designers can employ.

Seven Participants of varying eye-heights (1st, 29th, 50th, 82nd and 97th) completed an exercise study that provided insight into treadmill and upright bike fixed screen positions. The Participants were analysed in two exclusive user groups (50th%tile and 1st-99th%tile) and asked to rate three screen positions on viewing and touching preference while performing either a high or low-interaction activity. The first screen position was based on recommended literature anthropometric guidelines (AScP), the second from the manufacturers experience (EScP) and the third was self-selected by the Participants of the test (UScP). High-interaction activity consisted of the subject playing matched-pair card games during exercise, whilst low-interaction activity allowed users to watch and listening to the TV on-screen. The screen position with the highest preference rating was believed to be the most desirable. Screen viewing distance, viewing angle and reach distance were compared between the 3 screen positions and 2 activity tasks. Subject posture and distance from screen during exercise was also measured for comparison with literature.

All three screen positions were perceived to be ‘suitable’ across both user groups for both high- and low-interaction activities in the treadmill study. The 50th%tile user group preferred UScP more than EScP and EScP more than AScP. AScP position was deemed unsuitable during HI and LI activities by the 1st-99th%tile user group, again UScP was preferred. An overall screen height from treadmill belt and screen angle range was recommended between 1220-1280mm and 55-70° respectively.

During treadmill running, the user chooses to move fore-aft along the treadmill belt depending on the level of interaction with the screen. Users prefer to be further away from the screen when simply viewing the screen (low-interaction activity) compared to touching the screen (high-interaction activity). The mean increase in distance between tasks for Participants 1, 2 and 3 was 56mm (15%), 39mm (9%) and 111mm (22%) respectively. Consequently, mean viewing angle was reduced 1° (8%), 1° (6%) and 3° (22%) for Participants 1, 2 and 3 respectively. The preferred (UScP) viewing distance varied considerably between the three Participants in the 50th%tile user group. There was also no single viewing angle or distance which satisfied all Participants. Instead a distance and angle range during high activity of 350-500mm and 10-35°;

and viewing angle and distance range during low activity of 400-650mm and 10-30° was evident. Mean reach distance also varied considerably between Participants ranging from 400-550mm and 450-700mm for high- and low-activities respectively.

In the bike study, UScP was most preferred and again EScP was more preferred than AScP. Most of the Participants in the 50th %tile user group preferred a steeper screen angle, but height and distance from crank varied. Mean screen height, distance and angle across the 50th%tile group was 953mm, 574mm and 50.4° respectively. Again, a screen height, distance and angle range is recommended between 920-980mm, 550-600mm and 40-55° respectively.

A large range of body to screen position relationships was apparent because of the varying postures of the Participants. When the body is in a fixed position, as when sitting on a bike, the posture of the spine will greatly affect head position. Therefore an 'optimum' anthropometric based position for a person with neutral spinal alignment will differ from that based on a kyphotic-lordotic spine, for example. Postural differences should be considered in future studies.

This study is believed to be one of the first to document the use of visual and touch ergonomics during exercise and should be treated in this context. In Table 12, the relationship between the user and the test screen position was compared to ergonomic workstation standards. In the treadmill study, subject's viewing distance was generally lower (400-500mm) than literature (500-700mm), but viewing angles were similar (10-30°). When users self-selected a screen position they opted for a viewing distance of 450mm when interacting with the equipment (high-interaction activity) and 500mm when simply viewing the equipment (low-interaction activity). Head/neck angle during running was lower than recommended by Ankrum and Nemeth (2000), but no user experienced neck pain. In the bike study, viewing distance and angles of the three screen positions were lower than recommended in literature, but reach distance was comfortably within range.

It is interesting to consider the development of existing screen positions through expert opinion such as manufacturer experience in this study. Both user groups found the manufacturer screen position both desirable and easy to use. The development of a screen position through anthropometric measures alone (as in AScP) is not suitable; subtle user interactions and exercise effects can be missed.

The overarching aim of the study was to develop a structured methodology to investigate screen position in cardiovascular equipment. Improvements in this early study are suggested to provide a more robust test method for future studies, as detailed in Table 14.

Table 14: Procedure to investigate screen position ergonomics of cardiovascular equipment

	Task	Description
1	Literature review	Understand optimum range of viewing distance, viewing angle, reach distance and neck (or other body) discomfort.
2	Choose positions	Decide on anthropometric position and Technogym position based on experience
3	Subjective feedback when using equipment	Ask 5 users in each size category (5th, 25th, 50th, 75th, 95th percentile) to rate preference of distance, angle and height of each screen
4	User defined	Ask users to position screen in any position they feel would optimize their user experience
5	Anecdotal feedback	Ask users about screen controls, their experience using equipment and any other feedback
6	Analyze results	Discern difference in user defined vs. Technogym vs. anthropometric screen positions
7	Understand body position	With lack of data on cardiovascular equipment ergonomics, Technogym can begin to develop commonalities between posture/ screen positioning
8	Develop models	Develop models for range of user size categories and build up profile of user characteristics when exercising on equipment

5. Conclusion

A novel ergonomic assessment method was developed to best understand user preference of fixed touch-screen position when exercising on a treadmill and upright bike. Seven Participants of a broad range of eye-heights trialled anthropometric hypothesized, expert derived and user defined screen positions on both exercise equipment whilst interacting with the touch screens. Their preference for screen height, distance and angle were recorded and compared, with the aim of 'best' placing a fixed touch-screen position for 50th percentile eye-height user group. Measures of postural relationship to the screen were also recorded to aid future designers. A set of guidelines for future ergonomic trials have also been detailed to help understand screen positions of other popular cardiovascular exercise equipment.

In both the treadmill and bike study, 50th percentile Participants preferred the user defined screen position as expected, but there was little objection to the manufacturer's position which was preferred more than anthropometric devised. The anthropometric devised screen position was deemed unsuitable on occasions highlighting the lack of understanding in exercise ergonomics. Expert opinion from the manufacturer was within recommended screen heights, distances and angles recorded from this study. Future studies can employ the principles used in this study and develop this field of ergonomics with the ultimate aim of improving user experience during exercise.

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