Applied Ergonomics 45 (2014) 247 260

Contents lists available at SciVerse ScienceDirect

Applied Ergonomics

journal homepage: www.elsevier.com/locate/apergo

A literature review on optimum and preferred joint angles in automotive sitting posture

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ARTICLE INFO

Article history:
Received 14 September 2012
Accepted 8 April 2013

Keywords:
Joint angles
Optimum sitting posture
Automotive

ABSTRACT

In this study, a survey of the scientific literature in the field of optimum and preferred human joint angles in automotive sitting posture was conducted by referring to thirty different sources published between 1940 and today. The strategy was to use only sources with numerical angle data in combination with keywords. The aim of the research was to detect commonly used joint angles in interior car design. The main analysis was on data measurement, usability and comparability of the different studies. In addition, the focus was on the reasons for the differently described results.

It was found that there is still a lack of information in methodology and description of background. Due to these reasons published data is not always usable to design a modern ergonomic car environment. As a main result of our literature analysis we suggest undertaking further research in the field of biomechanics and ergonomics to work out scientific based and objectively determined "optimum" joint angles in automotive sitting position.

1. Introduction

In today's consumer society the availability and affordability of luxury products grows worldwide (de Looze et al., 2003; Yeoman and McMahon Beattie, 2006). For this reason, ergonomics and comfort design get more attention from industrial designers because designing ergonomically optimized products leads to popular products as seen by Apple's iPhone (Walker et al., 2009). In sales promotion ergonomic design is a growing factor and contentment and comfort is a frequently used phrase. The same development can be noted in the automotive industry (Kolich and Taboun, 2004; Franz et al., 2011). To be ahead of competition in the automotive industry, ergonomics and seating comfort need to be more focused on the car interior designing process (Zenk et al., 2009, 2012). The main reasons are the suburbanization of the cities, the increase of traffic jams, growing business and leisure travel. As such, people are spending more time in their cars (Hasselbacher and Schwaighofer, 2001; Frank et al., 2004; Lyons and Urry, 2005; Zenk et al., 2009). To avoid discomfort and fatigue it is necessary to investigate an optimum seating posture which can be adapted to the car (Andersson et al., 1974; Hanson et al., 2006).

To analyze seating posture and components needed for driving (e.g. steering wheel, pedals, gear selection lever, navigation systems or displays) manufacturers use 2D and 3D tools, especially CAD and digital human models (DHM). Most of DHM can be used to investigate vision, comfort, reachability, clearance and the driving posture in general. Although there are lots of studies, theoretical and laboratory/fieldtests (e.g. Hosea et al., 1986; Harrison et al., 2000; Oudenhuijzen et al., 2004), customers often complain of postural discomfort especially in the neck and shoulders, as well as of low back pain, which is an increasing disease in modern society (Magnusson and Pope, 1998; Andersson, 1999; Ebe and Griffin, 2001).

In order to achieve correct ergonomic design and comfort it is necessary to work with joint angles in DHM which have to be deduced from scientific studies in literature. On this topic Kyung and Nussbaum (2009) related to Reed et al. (2002), Hanson et al. (2006) and Chaffin (2007) claimed that: "With expanding use of digital human models (DHMs) for proactive as well as retrospective ergonomic analysis of automotive interior design, there is a concomitant need for accurately predicting and specifying driving posture" (p. 939). To obtain knowledge of sitting posture a few

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0003-6870/$ see front matter © 2013 Elsevier Ltd and The Ergonomics Society. All rights reserved.
http://dx.doi.org/10.1016/j.apergo.2013.04.009

studies have been undertaken with biomechanical methods, e.g. EMG, spine disc pressure investigations and shearing load in hu man joints in the field of sitting on office chairs (Andersson and Oertengren, 1974; Goossens and Snijders, 1995; Hasegawa and Kumashiro, 1998; Harrison et al., 1999). Research on the driver's workspace during car designing processes, and on optimum sitting posture with a focus on joint angles is mostly done with values of subjective comfort (e.g. Hanson et al., 2006), while studies using biomechanical methods like Andersson et al. (1974), Zenk (2009), Franz (2010) or Hosea et al. (1986) are rarely found. In addition, published material shows a large variance concerning optimum and comfort joint angles. Because of these differences described in literature it is necessary to decide on one source as discussed by Vogt et al. (2005).

The main aim of this work is to show which recommendations exist on optimum and preferred sitting posture and scientific evidence.

Nowadays, factors like human strength do not play an important role in cars anymore. Therefore, it is questionable whether opti mum driving posture should be defined on objective or on sub jective comfort and discomfort values.

Articles found in literature with available joint angles were discussed and compared in order to obtain a general overview. It was no matter whether the sitting angles were defined based on studies with biomechanical or physiological facts, or on the sub jective preferred posture.

Moreover, quite often a mixture of the expressions optimum and preferred joint angle is found in literature. Therefore we created a clear predefinition for these two expressions which we followed throughout the paper to make it easier for the reader.

In order to make clear statements we defined 'optimum joint angles' and 'optimum joint posture' to be dependent on biome chanical and physiological factors that, for example, lead to less muscular fatigue which in turn results in greater safety. 'Preferred joint angles' as well as 'comfortable joint angles' are indicated by subjective impressions and defined by the drivers' preferences.

However the preferred posture is only one part which in fluences the comfort and discomfort of the driver (Kyung et al., 2008).

In general there is a need for additional research for the opti mization of DHM with biomechanical methods. Precise joint angles for comfortable driving positions will improve ergonomic design when these factors are implemented in digital human models (Kyung and Nussbaum, 2009).

Therefore, this study focused on the investigation of similarities and discrepancies in methods, results and recommendations of scientific papers dealing with optimum and preferred joint angles in automotive sitting posture.

2. Methods

In order to identify the published papers in this field a literature research was carried out up to and including June 2012. To cover as much information as possible, four international databases (Science direct, Pubmed, Google Scholar, Medline), as well as three tradi tional libraries were analyzed: the library of the technical Univer sity of Munich, the library of the University of Applied Sciences of Munich and the Bavarian State Library. The following keywords were chosen: driver workspace, optimum driving posture, preferred driving posture, automotive driver posture and comfort angle. Additionally, the reference lists of the retrieved articles and books were inspected and the publication lists of the authors were checked. The results comprise scientific reviewed journals as well as standard literature such as traditional books on biomechanics, transport, cars, anatomy and ergonomics. The books were considered because several authors took them as a reference in their own investigations and since the textbook is currently in use. Articles were first screened by the researchers and checked on their relevancy based on their abstract or their title. Final selection of articles was done using following criteria: (1) the article had to be published in English, French or German and (2) the article had to show results reporting joint angles and optimum or preferred driving posture in concrete numerical data. Based on these criteria, a total of 30 articles were judged to be relevant for further exam ination. Table 1 shows the selected articles.

Thereupon the full papers were accessed and read by the au thors. The angles of several joints were compared with each other on their numerical outcome including standard deviation (SD). Further, study design and the methods used to obtain joint angles have been examined and compared. The original sources were separated into three groups: Articles with 1) theoretical deriva tions, no precise information about the origin of their data and literature reviews, 2) a 2D experimental design, 3) a 3D experi mental design.

The theoretical articles and the reviews were analyzed regarding the methods, strategies and the derivation and justifi cation of the results. Studies with an experimental design were investigated according to the methods (e.g. measurement method, laboratory or field test) and the number of participants. This was done in order to get an overview regarding the comparability of literature data. Further analysis has been undertaken on the topic of subjective or objective measurement and rating of the data. That means whether the subjects choose their position by their own preferred posture or the recommendation regarding the posture was given by medical, physiological or biomechanical aspects as defined above.

To get a good overview of the research method a concept model is included (see Fig. 1).

In order to get a comparable database several criteria were defined in a second selection round. In the section discussion a selection of the most relevant studies, based on following criteria is presented: given data origin, 3D measurement and experimental design data with more than 30 participants to find out the current state of comparable literature.

3. Results

According to the inclusion criteria of this examination, 30 ref erences in total, published between 1940 and 2009, which focused on optimum or preferred joint angles of the driver, were studied. Seven of them include an experimental test design with 2D data (e.g. Bubb, 1992), nine include an experimental design with 3D data (e.g. Andreoni et al., 2002) and 14 papers don't have an experi mental design. Five of these 14 describe results derived from theoretical considerations (e.g. Grandjean, 1980), four studies are literature reviews (e.g. Vogt et al., 2005) and the remaining five articles give no precise information about the origin of their data (e.g. Kahlmeier and Marek, 2000).

The number of investigated joints varies between one (Oudenhuijzen et al., 2004) and 16 (Kyung and Nussbaum, 2009), where all large human joints (neck, shoulder, elbow, wrist, torso, hip, knee, ankle), which are necessary for defining the human posture, and two angles of the vertebra were integrated. A huge range could be found concerning the number of subjects. It differs between four (Keegan, 1964; Andersson et al., 1974) and 250 (Lay and Fisher, 1940). Although several authors mentioned distribu tion of gender in the methods section of their papers, only a few of them presented gender specific results (Park et al., 2000).

28 studies investigated only one side of the human body, just Kyung and Nussbaum (2009) and Hanson et al. (2006) conducted