Lee and Jin *Fash Text* (2019) 6:23
https://doi.org/10.1186/s40691-019-0179-z

Fashion and Textiles

RESEARCH Open Access

Conceptual design framework as a model for wheelchair users' sportswear comfort

Hyojeong Lee[1] and HeeJae Jin[2*]

*Correspondence:
heejaejin@gmail.com
[2] Ph.D., School of Design and Human Environment, Oregon State University, 228 Milam Hall, Corvallis 97330, USA
Full list of author information is available at the end of the article

Abstract

The purpose of this study is to propose the necessary design framework to assess sportswear attributes in terms of comfort and enhanced performance for wheelchair users. The design framework, which is to integrate CCM (Clothing Comfort Model) into MCSN (Model for Clothing for Special Needs), determines the physical nature of personal characteristics to evaluate clothing comfort needs for wheelchair users. This newly suggested design model contains personal characteristics, degree of physical disability and physical dimension. Within the physical dimension category, there are activity and fit attributes which come from the comfort concept. In this new design framework, the activity including having wheelchair users' own special activity and fit related to clothing comfort show the necessary comfort attributes. The new design model is applied with some previous study cases and further analyzed. This study provides clear strategies for identifying the comfort aspect when designing sportswear for wheelchair users and does so by offering a new conceptual model. These examinations would allow development of useful guidelines for both best comfort and appropriate design dimensions for sportswear for wheelchair users.

Keywords: Sportswear, Comfort, Design model, Wheelchair users, Physical disability, Clothing attributes

Introduction

The conceptual design framework has been represented as a synonymous term for the model (Choosakul et al. 2009; Visek et al. 2009; He et al. 2006; Lai 2007). Choosakul et al. (2009) explained their model as "a conceptual framework that helps to better understand motivational factors that predict commitment in sport settings". Authors have used conceptual framework to describe their strategic system as a model. Therefore, these two terms are interchangeably used.

Model has been used to identify variables that influence the outcome (Au et al. 2006). In certain situations, the model can estimate and predict the outcome (Askari and Krichene 2010; Rasmussen et al. 2010; Silber et al. 2010). Choosakul et al. (2009) mentioned that model "helps to better understand motivational factors that predict" outcome in the theoretical constructs.

In this respect, the development of sportswear as the functional clothing design needs to be approached in the theoretical constructs so models can be used to better understand and to identify certain demands in a given situation. For example, the demand of

having nonrestrictive full range of motion for exercise garments can be explained by the model if this is approached in theoretical construct. Wheelchair users, especially, require different needs for their sportswear during their performance and have varying body movements due to their degree of disability. However, there are still only limited studies regarding sportswear for wheelchair users that are based on their body movements. Wheelchair user's movements encompass wheeling their chair and, in certain sports, reaching the ball from a seated position. Able-bodied users do not perform these movements, so these different movements performed by wheelchair users were not considered when constructing the general sportswear. Thus, it is evident that wheelchair users' specific demands must be taken into account when constructing their sportswear. In this respect, type of activity or movement needs to be incorporated in the model for development of wheelchair users' sportswear.

For better movement during sports play, comfort needs to be considered as an important factor when creating sportswear. Comfort is defined as "A state of physical and material well-being, with freedom from pain and trouble, and satisfaction of bodily needs; the condition of being comfortable" (Oxford University Press, 1961). While there are many prior researches performed on comfort of clothing, the method of measuring and analyzing the level of comfort in each research varies based on its purpose of the study. For instance, Cho (2006) identified three categories of comfort—functional comfort, physiological comfort, psychological comfort—in order to design clothing based on comfort. Liu and Little (2009) also asserted that the comfort of functional performance of sport wear is largely determined by complex interactions between multiple factors, such as material physical structure and mechanical properties, thermal and moisture regulatory properties, the size and shape of the body to which it is applied, the corresponding dimensions of designed athletic wear, the nature and levels of physical activity. Based on their findings, they suggested the 5Ps model (Physical, Physiological, Psychophysiological/Physiological Psychology, Psychological, Psychophysical). Moreover, in the designing of functional sportswear, garment comfort is a crucial factor for ease of movement (McRoberts et al. 2015). This is also true for people with physical disability because many of these individuals have reported to prefer comfortable clothes for ease of movement and for better fit in their sportswear (Carroll and Kincade 2007). Based on these facts, the proposed model can evaluate the most appropriate comfort in a given situation for wheelchair users. Therefore, the purpose of this study is to suggest the design framework needed to identify sportswear attributes, such as activity and fit, for wheelchair users' satisfaction based on comfort.

Literature review

Disabilities of wheelchair users' classification

Paraplegia and quadriplegia

Paraplegia and quadriplegia result from injury to the spinal column. Based on the location of the injury, the terms paraplegia and quadriplegia can be classified and defined. In other words, quadriplegia is more severe, as it affects all four limbs, whereas paraplegia is a paralysis condition where only the lower limbs are affected. In the quadriplegia, the injury of the cervical segments (C1 to C8) affects the function of the arms, trunk, legs,

and pelvic organs (Figoni 1997). The level of C1 to C5 injuries require total assistance for transferring from bed to wheelchair and for bathing activities, since potential movements occur between the limited respiratory and partial shoulder movement (Morgulec et al. 2005).

People with C6 to C8 injuries need some assistance for daily living activities involving extension of the arm. In addition, C8 can grasp with able finger flexion and extension. With paraplegia, activities of daily living can be more independent, for example, as eating, dressing or bed and wheelchair transfers (Institute of Medicine 2005). In paraplegia, three levels of conditions include the area of control for the thoracic cord section (T1 to T12) as in the chest, abdominal muscles; hips and legs in the lumbar (L1 to L5); and sacral (S1 to S4) spinal cord levels, which control bowel, bladder, groin, buttocks, and legs. Based on the condition, the level of paraplegia movement falls between throwing with holding and movement of the trunk. Herrmann et al. (2011) identified the differences in the functions of people with quadriplegia and paraplegia based on the International Classification for Functioning, Disability, and Health (ICF). Their results indicated that people with quadriplegia had a significantly higher risk of body function problems compared to people with paraplegia, including pressure sores, thermoregulatory functions like cooling sweat reaction, mobility of joint functions, and blood pressure function even though both individuals with paraplegia and quadriplegia will have impaired sensation. In addition, the interconnection of the hand and arm use relates to upper movement in people with quadriplegia and has been shown to have a higher risk due to the higher lesions from motor loss. Even though researchers have indicated there are differences in body functions and self-care for people with quadriplegia and paraplegia, there is no significant difference in their interpersonal interactions with their communities and social lives.

The Various approaches of development of the design method

The design method based on comfort theory

Barker and Black (2009) investigated the needs of police officer clothing based on clothing comfort theory. Researchers for this study attempted to address more of the attributes from a physical dimension of clothing system, fit, and properties, than the social-psychological dimension. The findings showed that the ballistic vest fit and properties included acceptable, bulky, sturdy, and easy to put on characteristics, which significantly correlated to clothing comfort. Even though many researchers indicated psychological comfort could improve the physical performance for wearers, previous researches stated that physical dimension had a more efficient correlation to comfort than did the psychological dimension.

Cho (2006) addressed aspects of comfort to assess the satisfaction evaluation of the patient garment and then proposed prototypes based on the end user's needs. To measure the needs of patients and evaluate wearer trial evaluations, questionnaires were conducted for Clothing Comfort (Branson and Sweeney 1991). The questionnaire included three categories:

1. Functional comfort: Accommodation to activities, easy reach of fasteners, and ease of donning/doffing;
2. Physiological comfort: Sensorial comfort, thermal comfort, fit and fabric weight; and
3. Psychological comfort: Aesthetic/expressive satisfaction, suitability for daily life in a hospital, and privacy and dignity.

In the proposed two types of prototypes, prototype A was more comfortable in terms of functional aspects than were the traditional hospital garments. Prototype A included 5 features: A front opening; enclosed raglan sleeves; a triangular-shaped, free-float area in the front; and a back-slit overlap. Prototype B offered higher psychological comfort than the traditional hospital garments. Prototype B included 4 features: Cap sleeves; a front-slit overlap; openings on the upper chest area; and an opening from the armpit to the hem on the right side (Cho 2006).

Mitchka et al. (2009) assessed the needs of female dancewear based on satisfaction with dancewear by women who attended universities' dance classes. In the result, the needs of fashion factor were related to the comfort factor even though these researchers did not define that specific comfort dimension (Mitchka et al. 2009). Laing and Ingham (1985) evaluated a heat protective clothing system through the physical and psychological determinants of comfort. Physical determinants included comfort in relation to fabric contact with the skin, comfort influenced by level of work related to a garment system, and the effects dependent on different body locations. Evaluation of comfort with psychological dimensions was a subjective measurement, including the effects with the sensation by its physiological basis. The findings indicated that thermal sensation showed significant differences for the various regions on the body, and visual assessment of garment fit and size variable was identified as the one of the essential comfort evaluations. Therefore, the concept of comfort related to clothing is very broad, so researchers analyze it in different categories of the physical, social-psychological, or the physiological domain of comfort.

The design method for development of wheelchair users' clothing

When studying clothing for wheelchair users, many researchers have studied the topic in various approaches. Lamb (1993) suggested that the social psychological aspects of clothing for people with disabilities should not be overlooked. Traditionally, the relative appearance for people with physical disabilities in society is evaluated through the third-party perceivers, stimulus persons, and the context in the social psychological approach. However, it is important to develop clothing using multiple considerations including social desirability, protection, comfort felt by people with disabilities, and consumer satisfaction (Lamb 1993) instead of development just based on appearance. Lamb (2001) identified the societal issues in researching for people with disability in the context of clothing and textiles scholarly fields. These included barriers to access, equal opportunity, images, and identity. The concept of accessibility means how people with disabilities use their athletic clothing in different social settings, like for special occasions including parties. The researcher stated that specialized clothing lines could be designed to satisfy consumers with disabilities and resolve the barrier to access issues. In addition, the researcher suggested that scholars should consider equal opportunity to limit the sources of desired garments. Images and identity based on appearance also should

be considered to understand the social view of people with disabilities (Lamb 2001). Finally, Lamb (1991) finally suggested that it was especially important to consider both the social psychological aspect and the physical condition when designing garments for people with disabilities.

Feather (1991) further emphasized the physical condition aspect to design conceptual framework for garment of people with disabilities. The researcher defined clothing for special needs as clothing that "reduces or eliminates the barrier to an individual's social, functional, or economic functioning resulting from a permanent physical, mental, and/or visual condition that might otherwise be stigmatizing and set them apart from the majority of the population". The researcher proposed a conceptual framework for clothing for special needs addressing three dimensions: personal characteristics, one's ability, and clothing. In the aspect of achieving the clothing attributes related to the comfort aspect and developing a design concept for wheelchair users, Feather's concept aligns with this study. Thus, this conceptual framework is used as one of the two major models to develop the new design model for wheelchair sportswear. In this study, Feather's framework, the Model for Clothing for Special Needs, will be called as MCSN.

Wheelchair users' sportswear

People with physical disabilities who have a paraplegic or spinal cord injury train using upper-extremity exercise to improve their cardiovascular fitness (Roy et al. 2006). For example, wheelchair tennis is used for rehabilitation and also as a competitive sport. However, wheelchair tennis requires a high level of aerobic fitness since movement during wheelchair tennis can be both intermittent and multidirectional (Roy et al. 2006). Also, hot and humid climates can bring great discomfort during such aerobic activity, which is an issue that researchers are studying in functional clothing design. For instance, Goosey-Tolfrey et al. (2008) asserted that wearing head and neck cooling garments reduce the feelings of thermal discomfort during wheelchair tennis play and improved performance. Kratz et al. (1997) explored the difference between adapted clothing and non-adapted clothing for wheelchair users that affected physical activity and comfort during exercise. In physical activity, wheelchair users who were sailing reported that less effort was experienced with the adapted clothing when using the toilet and moving between their wheelchair and the boat. In terms of comfort, the wheelchair users reported a significant difference in comfort when wearing adapted clothes compared to non- adapted clothing. The following briefly shows researches on comfort aspect for wheelchair sportswear.

Dec et al. (2000) indicated that exercise capacity is limited through venous blood pooling caused by the impairment of autonomic neural control. During exercise, wheelchair athletes need to use an abdominal binder to minimize venous blood pooling. Especially, researchers have suggested wearing positive pressure garments, such as stockings. Pearce et al. (2009) confirmed that sports compression garments increased during competition performance. The researchers also indicated that compression garments are used to assist motor functioning for people with cerebral palsy.

For sportswear, physiological aspect is an essential perspective for the effective performance of athletes (Hassan et al. 2012). To improve thermal comfort, i.e., the sensations of hot, cold, or dampness in clothes, the human body sweats during exercise to

run efficiently. Researchers explored the thermal properties to measure thermal comfort through thermal conductivity, which indicates the ability of a fabric to conduct heat, thermal absorptivity that indicates the warm-cool feeling of fabrics, and thermal resistance that indicates the effectiveness of fabric insulation. Therefore, researchers sought improved thermal comfort through the influence of sportswear fabric properties on the physiological responses because a wearer's heat loss can occur dramatically through vaporization moisture within the clothing. The finding indicated that 100% polyester provided the best physiological responses. However, because wheelchair athletes with spinal cord injury have an impaired thermoregulatory capacity (Bhambhani 2002), researchers should consider heat exhaustion and heat stroke during wheelchair athletic exercise when designers developed their sportswear.

Among the many researches done on clothing based on comfort, Branson and Sweeney developed the Clothing Comfort Model that presents a conceptual framework to relate comfort to clothing. This study will utilize this model to address comfort when developing wheelchair users' sportswear, and will refer to the model as CCM.

Methods

Synthetic models to develop sportswear attributes for wheelchair users

To determine the necessary comfort attributes for wheelchair users' sportswear, the Model for Clothing for Special Needs (MCSN) (Feather 1991) and the Clothing Comfort Model (CCM) (Branson and Sweeney, 1991) are combined.

The Model for Clothing for Special Needs (MCSN)

In order to meet wheelchair users' satisfaction for their sportswear, this paper should recognize the different clothing needs based on the varying degree of disability. In this respect, a part of Model for Clothing for Special Needs (MCSN, Feather 1991) (Fig. 1) is used for this study. The MCSN is a model showing the step-by-step process of selecting

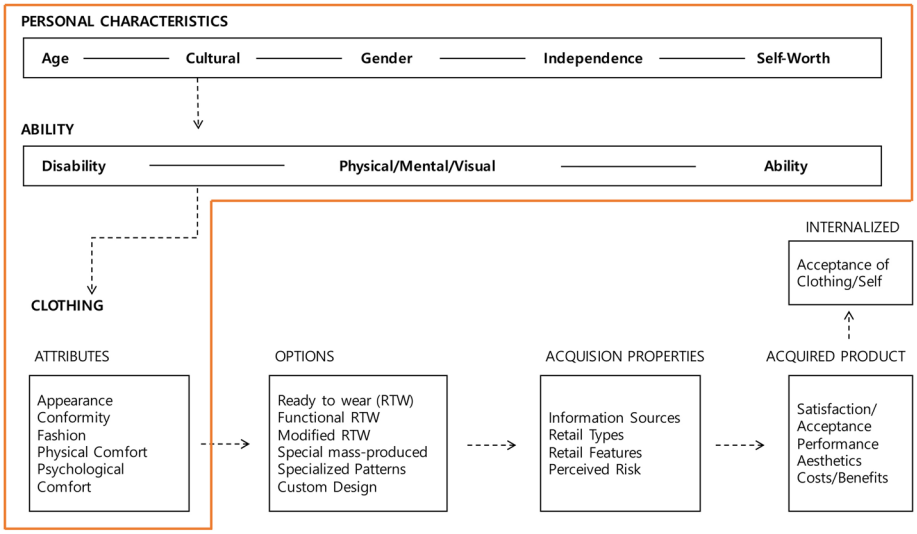

Fig. 1 Model for Clothing for Special Needs (MCSN) (Feather 1991): For the purpose of this study, only the section framed by the orange line will be considered

clothing for people with disabilities. In the MCSN, the researcher proposed a conceptual framework for clothing for those with special needs using three dimensions: personal, ability, and clothing. Within the personal dimension, age, cultural values, gender, economic status, independence, and self-worth were precisely considered. Age attribute includes individuals with the maturity to seek physical comfort in their clothing. In the gender attribute, different attitudes toward clothing between males and females are reported when they evaluate their clothing.

Ability dimensions include physical ability, visual ability, and mental health ability. Physical ability is assessed in terms of clothing issues, such as how putting on clothing depends on the level of mobility. The researcher finally introduced the clothing dimension which align more closely to the actual clothing selection processes. The elements in the clothing dimension include: clothing attributes, options, acquisition of clothing, acquired products, and internalized acceptance of clothing and thus the self. These elements are investigated in order as shown to arrive to the appropriate design. The clothing attributes within the clothing dimension of MCSN encompass appearance, conformity, fashion, as well as physical and psychological comfort. Among people with disabilities, "Ready-to-wear" in the clothing options element was selected more often than specialized pattern garments because people with disabilities tend to want to reduce the general stigma associated with a disability and increase their self-worth. The last step of MCSN was determining internalized acceptance. The researcher saw that specialized garment designed to meet comfort or self-help was well accepted when necessary modifications were less conspicuous or less visible (Feather 1991). For this study, the "attribute" element of clothing within the clothing dimension of MCSN was explored in-depth (see Fig. 1). Particularly, the comfort element in the clothing "attribute" was examined and the CCM model was applied into this section for wheelchair users' sportswear.

The Clothing Comfort Model (CCM)

Additionally, in order to develop wheelchair sportswear, comfort needs to be considered as the most important factor as seen in various literature review. Accordingly, the Clothing Comfort Model (Branson and Sweeney 1991) (Fig. 2) should be considered to determine the design criterion from the comfort perspective. The Clothing Comfort Model (CCM) has two dimensions, physical and social-psychological, to explain comfort attributes. Subsequently, each dimension includes three components: people, clothing, and the environment. The different comfort component for the physical dimension are:

1. People: Sex, age, race, weight, height, physical condition, activity, and the exposed surface area;
2. Clothing: Fabric characteristics, fiber content, yarn, fabric structure, finishes, color, fabric/clothing system, heat transfer properties, moisture/vapor transfer properties, air permeability, clothing system, fit, and design;
3. Environment: Air temperature, radiant temperature, wind velocity, ambient, vapor, and pressure.

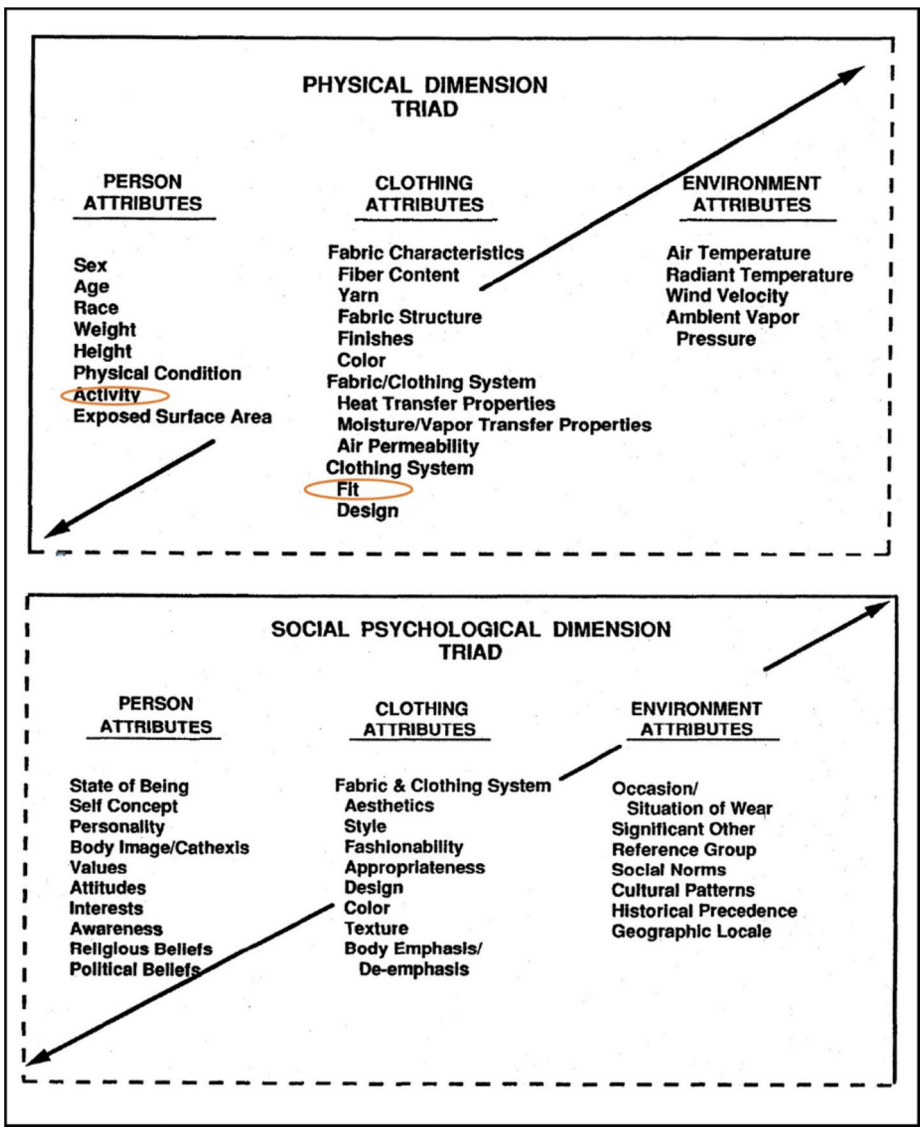

Fig. 2 Clothing Comfort Model (CCM) (Branson and Sweeney 1991): This study will only consider Activity and Fit attributes as the crucial factor to address comfort aspect

Comfort attributes of the social-psychological dimension are:

1. People: State of being, self-concept, personality, body image/cathexis, values, attitudes, interests, awareness, religious beliefs, and political beliefs;
2. Clothing: Fabric/clothing system, aesthetics, style, fashionability, appropriateness, design, texture, body emphasis/de-emphasis;
3. Environment: Occasion/situation of wear, significant other, reference group, social norms, cultural patterns, historical precedence, and geographic locale.

Since comfort is defined as "a state of satisfaction indicating physiological, social psychological and physical balance among a person, his/her clothing, and his/her

environment" (Branson and Sweeney 1991; Chattaraman and Rudd 2006), comfort attributes should be approached using these multiple dimensions.

Since the term "comfort" lies within a more complex phenomenon, the CCM model was simplified into essential factors based on literature review. The Clothing Comfort Model (CCM) includes comfort attributes for both physical and social-psychological dimensions. Each of these two dimensions address three components, namely, people, clothing, and the environment as mentioned above. However, for this study, the comfort was seen in the physical dimension more so than the social-psychological dimension. This is because the purpose of development of sportswear prioritize function and performance over social elements. Furthermore, two comfort elements within this dimension were examined. Comfort related to activity attribute was pulled out from the people component based on prior literatures, stating comfort was associated with a person's activity. As fit is a crucial area in the clothing and textile area, the fit attribute was proposed to measure clothing comfort to address the physical attributes. Therefore, comfort related to activity and fit were considered for this study.

Result and discussion

The new design framework for wheelchair users' sportswear

The new design framework of sportswear development for wheelchair users was the integration of CCM into MCSN. This study is to show a suggested design framework to determine the physical condition of users, their personal characteristics, and also assess the needs wheelchair users have for specific clothing comfort. The suggested design framework is displayed in Fig. 3.

In this proposed model of comfort concept, wheelchair users' characteristics and the degree of physical disability are associated with their clothing attributes. The personal characteristics in this model include age and gender. Feather (1991) asserted that researchers should determine focus group for their research since the clothing attitude differs between groups. (Feather 1991). For example, there are differences between

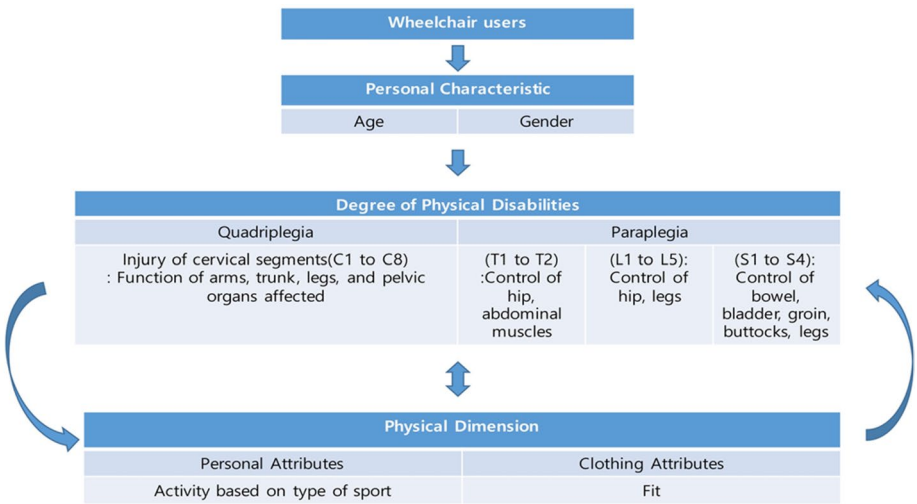

Fig. 3 The proposed model for wheelchair users' sportswear comfort

genders in attitude toward functional clothing for wheelchair users. Wingate et al. (1986) stated that "females viewed the salient functional clothing features more positively than did the males".

This study also suggests that age aspect needs to be considered for the personal characteristic dimension. Kidd (2006) detected that young women with special needs considered personal attractiveness and self-confidence for their clothing fit. Whereas older women with disabilities wanted a comfort aspect for their clothing, such as a "soft fabric", and clothing that was easy to don and doff as a functional aspect. Functional features were based on needs and contributed to developing the clothing for handicapped elderly women, such as a one-piece dress with full-length raglan sleeves, an elasticized waist, large patch pockets, a long front zipper opening, and length falling below the knees (Phipps 1997). Those findings are supported that the age factor is essential to show the different demands in the comfort aspect.

Feather (1991) asserts that the degree of physical disabilities affects the selection of clothing. Since the degree of physical disabilities have different medical issues and movement, this proposed model also presents the various degree of physical disabilities, notably paraplegia and quadriplegia. Curtis et al. (1999) investigated that people with quadriplegia reported more significant shoulder pain experienced than wheelchair users with paraplegia. In addition, Dec et al. (2000) indicated that T-6 and above spinal cord injury athletes have medical issues, such as reports of pressure sores that are present due to prolonged sitting and positioning of the knees higher than the hips. Dec et al. (2000) suggested that wheelchair athletes should be provided appropriate cushioning and wear absorbent fabric to reduce skin moisture and relieve pressure sores. These findings support that the proposed model identifies the various degree of disabilities and needs to be incorporated into wheelchair users' sportswear.

This proposed model offers that the activity and the fit attributes in the physical dimension are addressed to guide the development of sportswear of wheelchair users. The activity in the physical dimension needs to be identified since wheelchair users have their own special activity, such as wheeling their chairs. For example, wheelchair athletes, such as wheelchair tennis and rugby, have movement of the arms and torso instead of the movement of the lower torso and the legs. The unique movements of upper-body of wheelchair athletes produce more enhanced strain compared to lower body exercise (Armstrong et al. 1995). Indeed, 68% of wheelchair athletes have reported some type of upper-extremity pain (Yildirim et al. 2010). Especially, shoulder injury or pain occurs from overuse, lack of lumbo-pelvic postural control, poor shoulder flexibility, and repetitive overhead arm positioning were seen at between 30 and 52%. Many researchers stated that a dysfunctional sitting posture adversely affected the glenohumeral joint. Seelen and Vuurman (1991) suggested that dynamic trunk control can allow a more stable postural position for performing functional tasks using only the upper extremities. This is why activity must be especially considered for improvement in comfort for these individuals when making their sportswear under the physical dimension.

In this design model, fit attribute is approached under the physical dimension to develop the sportswear for wheelchair users. Fit is also intimately related to clothing comfort as supported by Kidd (2006) and Thoren (1996). Furthermore, Clarke (2010) asserted that wheelchair users reported that poorly fitting trousers can lead to lower

self-esteem and skin infection (Clarke 2010). These problems with garment fit often lead to garment alterations among people with physical disabilities (De Klerk and Ampousah 2002). Based on these findings, this new design model shows that fit aspect is also crucial to explain the necessary comfort attributes.

This study can suggest the sub dimension which can improve the fit attribute for the sportswear for wheelchair users depending on the activity. For example, in the aspect of the sizing and pattern development, the fit factor can be adjusted through the adjustment lines and amount of ease of the block pattern or design and style detail elements. In this respect, when the bodice pattern is developed, the measurement of torso depending on ROM (Range of Movement) of the trunk, shoulder and neck which include the girth factors (the width of chest and west of front back) and the length factors (armhole depth, center front and back length, shoulder angle of left and right, neck width and depth, and sleeve crown height and width) can differ. Additionally, it can be helpful in determining which is more useful between set-in sleeve and raglan sleeve. This study can be suggested particularly to identify the unbalanced measurement of bodice for wheelchair users and the difference of the wearing ease for the bodice and sleeve when developing the pattern in the physical dimension of this study since the difference of the measurement between front and back or left and right needs to be considered for those with varying degrees of disability, unlike people without disability. Design elements can be applied for the comfort aspect in the clothing system. For example, the garment shaping devices such as dart, tucks, pleats, and gathers can be considered to provide optimal wearing ease for the required area. Other design materials such as elastic, velcro, snap zipper and draw cord can be applied using fasteners to change style and aesthetic. However, since this study concentrates on physical dimension of comfort as the functional aspect for the development of sportswear within the synthetic model for the wheelchair users, the design system including color, silhouette and line would not be discussed in detail.

Conclusions

This study provides clear strategies for identifying the comfort aspect when designing sportswear for wheelchair users and does so by offering a new conceptual model. This new model approaches the unique phenomena by examining personal characteristics and the degree of physical ability. These examinations would allow development of useful guidelines for both best comfort and appropriate design dimensions for sportswear for wheelchair users.

Future study

In the Clothing and Textiles design scholarship, the design conceptual framework is used to develop clothing for specific purpose to explain their phenomenon. This study proposes the model as the design conceptual framework for the development of wheelchair users' sportswear. The suggested model in this study indicates that activity and fit design attributes need to be considered to improve comfort for the development of wheelchair users' sportswear. Further research should explore how to identify activity and fit to improve comfort for wheelchair users during movement. For example, since this model suggests that the activity factor is effectively attributed in the physical dimension, the

type of movements should be analyzed to enhance the performance for their sportswear. In addition, for fit attribute, future research can determine what clothing elements are effective to satisfy wheelchair users, and how to explore improving fit in-depth within this suggested model. Other elements within the proposed design framework can be explored in detail, such as aesthetics elements of color or silhouette that can appeal to fashion satisfaction for wheelchair users.

Abbreviations
CCM: Clothing Comfort Model; MCSN: Model for Clothing for Special Needs.

Authors' contributions
HJ designed the study and collected the data. HL and HJ participated in analyses and writing of the manuscript. HL guided the result and conclusion sections. All of the authors contributed to the formatting and editing of the manuscript. All authors read and approved the final manuscript.

Author details
[1] Assistant Professor, College of Natural Sciences, Department of Fashion Design & Merchandising, Gongju National University, 56, Gongjudaehak-ro, Gongju 32588, Republic of Korea. [2] Ph.D., School of Design and Human Environment, Oregon State University, 228 Milam Hall, Corvallis 97330, USA.

Acknowledgements
Not applicable.

Competing interests
The authors declare that they have no competing interests.

Availability of data and materials
Not applicable.

Ethics approval and consent to participate
Not applicable.

Funding
None.

Publisher's Note

Received: 31 December 2018 Accepted: 15 March 2019
Published online: 07 August 2019

References

Armstrong, L. E., Maresh, C. M., Riebe, D., Kenefick, R. W., Castellani, J. W., Senk, J. M., et al. (1995). Local cooling in wheelchair athletes during exercise-heat stress. *Medicine and Science in Sports and Exercise, 27*(2), 211–216.

Askari, H., & Krichene, N. (2010). An oil demand and supply model incorporating monetary policy. *Energy, 35,* 2013–2021.

Au, K. F., Wong, W. K., & Zeng, X. H. (2006). Decision model for country site selection of overseas clothing plants. *The International Journal of Advanced Manufacturing Technology, 29,* 408–417. https://doi.org/10.1007/s00170-005-2505-4.

Barker, J., & Black, C. (2009). Ballistic vests for police officers: using clothing comfort theory to analysis personal protective clothing. *International Journal of Fashion Design, Technology and Education, 2,* 59–69.

Bhambhani, Y. (2002). Physiology of wheelchair racing in athletes with spinal cord injury. *Sports Medicine, 32,* 23–51.

Branson, D. H., & Sweeney, M. (1991). Conceptualization and measurement of clothing comfort: Toward a meta theory. In S. B. Kaiser & M. L. Damhorst (Eds.), *Critical linkages in textiles and clothing: Theory, method and practice* (pp. 94–105). Monument: International Textile and Apparel Association.

Carroll, K., & Kincade, D. (2007). Inclusive design in apparel product development for working women with physical disabilities. *Family and Consumer Sciences Research Journal, 35,* 289–315.

Chattaraman, V., & Rudd, N. A. (2006). Preferences for aesthetic attributes in clothing as a function of body image, body cathexis and body size. *Clothing and Textiles Research Journal, 24*(1), 46–61.

Cho, K. S. (2006). Redesigning hospital gown to enhance end users' satisfaction. *Family and Consumer Sciences Research Journal, 34,* 332–349.

Choosakul, C., Vongjaturapat, N., Li, F., & Harmer, P. (2009). The sport commitment model: An investigation of structural relationships with Thai youth athlete populations. *Measurement in Physical Education and Exercise Science, 12,* 123–139.

Clarke, R. (2010, June). Cyborg rights. In *Technology and Society (ISTAS), 2010 IEEE International Symposium on* (pp. 9-22). IEEE.

Curtis, K., Drysdale, G., Lanza, R., Kolber, M. & Vitolo, R. (1999). Shoulder pain in wheelchair users with tetraplegia and paraplegia. *Archives of Physical Medicine and Rehabilitation, 80,* 453–460.

de Klerk, H. M., & Ampousah, L. (2002). The physically disabled South African female consumer's problems in purchasing clothing. *International Journal of Consumer Studies, 26,* 93–101.
Dec, K. L., Sparrow, K. L., & Mckeag, D. B. (2000). The physical-challenged athlete: Medical issues and assessment. *Sports Medicine, 29*(4), 245–259.
Feather, B. L. (1991). Clothing for people with special needs: A proposed model to examine personal dimensions, clothing selection processes, and personal self-acceptance. *Critical linkages in textiles and clothing subject matter: Theory, method, and practice* (116–124).
Figoni, S. F. (1997). Spinal cord injury. *ACSM's Exercise Management for persons with chronic diseases and disabilities* (175–179).
Goosey-Tolfrey, V. L., Diaper, N. J., Crosland, J., & Tolfrey, K. (2008). Fluid intake during wheelchair exercise in the heat: effects of localized cooling garments. *International Journal of Sports Physiology and Performance, 3*(2), 145–156.
Hassan, M. F., Saman, M. Z. M., Sharif, S., & Omar, B. (2012). Integration of morphological analysis theory and artificial neural network approach for sustainable product design: a case study of portable vacuum cleaner. *International Journal of Sustainable Manufacturing, 2*(4), 293–316.
He, J., Chin, K., & Zhu, D. (2006). Return policy model of supply chain management for single- period products. *Journal of Optimization Theory and Applications, 129*(2), 293–308.
Herrmann, K. H., Kirchberger, I., Biering, F., & Cieza, A. (2011). Differences in functioning of individuals with tetraplegia and paraplegia according to the International Classification of Functioning, Disability and Health (ICF). *Spinal Cord, 49*(4), 534–544.
Institute of Medicine. (2005). *Spinal cord injury: Progress, promise, and priorities*. Washington, DC: The National Academies Press.
Kidd, L. K. (2006). A case study: Creating special occasion garments for young women with special needs. *Clothing and Textiles Research Journal, 24*(2), 161–172.
Kratz, G., Söderback, I., Guidetti, S., Hultling, C., Rykatkin, T., & Söderström, M. (1997). Wheelchair users' experience of non-adapted and adapted clothes during sailing, quad rugby or wheel–walking. *Disability and Rehabilitation, 19*(1), 26–34.
Lai, C. (2007). The theory of intelligent design decision making model on human—apparel system design. *International Journal of Computer Science and Network Security, 7*(8), 120–127.
Laing, R. M., & Ingham, P. E. (1985). Patterning of objective and subjective responses to heat protective clothing system: Part 2 Subjective measurements of comfort. *Clothing and Textiles Research Journal, 3,* 31–34.
Lamb, M. (1991). Clothing for people with special needs: Some conceptual issues. *International Textile and Apparel Association (Special Publication), 4,* 109–115.
Lamb, J. M. (1993). Physical disability as an aspect of appearance. *ITAA special publication*, *5*.
Lamb, J. M. (2001). Disability and the social importance of appearance. *Clothing and Textiles Research Journal, 19*(3), 134–143.
Liu, R., & Little, T. (2009). The 5Ps model to optimize compression athletic wear comfort in sports. *Journal of Fiber Bioengineering and Informatics, 2*(1), 41–52.
McRoberts, L. B., Black, C. M., & Cloud, R. M. (2015). Evaluation of a prototype soft-structured thoracic posture support garment. *Clothing and Textiles Research Journal*.. https://doi.org/10.1177/0887302X15622571.
Mitchka, J., Black, C., Heitmeyer, J., & Cloud, R. (2009). Problem structure perceived: Dance practicewear needs of adult female dance students. *Clothing and Textiles Research Journal, 27*(1), 31–44.
Morgulec, N., Kosmol, A., Vanlandewijck, Y., & Wonzniak, E. (2005). Anaerobic performance of active and sedentary male individuals with quadriplegia. *Adapted Physical Activity Quarterly, 22,* 253–264.
Oxford University Press (1961). *The Oxford English dictionary*. Oxford
Pearce, A., Kidgell, D., Grikepelis, L., & Carlson, J. (2009). Wearing a sports compression garment on the performance of visuomotor tracking following eccentric exercise: A pilot study. *Journal of Science and Medicine in Sport, 12,* 500–502.
Phipps, C. A. (1997). Clothing design for handicapped elderly women. *Journal of Home Economics*, *69*(4), 21–23.
Rasmussen, S., Fraser, L., Gotz, M., MacHale, S., Mackie, R., Masterton, G., et al. (2010). Elaborating the cry of pain model of suicidality: Testing a psychological model in a sample of first-time and repeat self-harm patients. *British Journal of Clinical Psychology, 49,* 15–30. https://doi.org/10.1348/014466509X415735.
Roy, J. L., Menear, K. S., Schmid, M. M., Hunter, G. R., & Malone, L. A. (2006). Physiological responses of skilled players during a competitive wheelchair tennis match. *Journal of Strength and Conditioning Research, 20*(3), 665.
Seelen, H. A., & Vuurman, E. F. (1991). Compensatory muscle activity for sitting postureduring upper extremity task performance in paraplegic persons. *Scandinavian Journal of Rehabilitation Medicine, 23,* 89–96.
Silber, J. H., Rosenbaum, P. R., Brachet, T. J., Ross, R. N., Bressler, L. J., Shoshan, O., Lorch, S. A., & Volpp, K. G. (2010). The hospital compare mortality model and the volume outcome relationship. *Health Service Research, 45*(5), 1148–1167.
Thoren, M. (1996). Systems approach to clothing for disabled users. Why is it difficult for disabled users to find suitable clothing. *Applied Ergonomics, 27*, 389–396.
Visek, J. A., Harris, S. B., & Blom, C. L. (2009). Doing sport psychology: A youth sport consulting model for practitioners. *The Sport Psychologist, 23,* 271–291.
Wingate, S. B., Kaiser, S. B., & Freeman, C. M. (1986). Salience of disability cues in functional clothing: A multidimensional approach. *Clothing and Textiles Research Journal, 4*(2), 37–47.
Yildirim, N. U., Comert, E., & Ozengin, N. (2010). Shoulder pain: A comparison of wheelchair basketball players with trunk control and without trunk control. *Journal of Back & Musculoskeletal Rehabilitation, 23*(2), 55–62.