

Yoga sportswear design, functional attributes and wear comfort properties: a review

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Abstract:

Yoga is a static recreational exercise, in which people engage in physical activity, but do not train for competition. Despite its growing popularity and potential health benefits, yoga sportswear is extremely understudied in terms of apparel design, functional attributes, and comfort properties. This paper aims to review the appropriate sportswear design for yoga and the significance of common functional attributes influencing wearing comfort. The second aim is to identify the main aspects of sportswear's comfort properties and methods for evaluating the comfort properties. The review shows that there are no specific designs made for yoga sportswear. However, several common apparel elements are typically used for yoga, which include sports bras, tank tops and leggings. Each element has a few design criteria to improve wearer performance and prevent discomfort. In addition, garment fit, stretchability and protection are the three functional attributes of yoga sportswear that are just as important as the other basic sportswear functions addressed in previous studies. Meanwhile, each aspect of comfort properties, such as thermo-physiological, psychological, skin sensorial and ergonomic comfort, are essential and relates to one another in contributing to wearer comfort. The review also found that there are two methods to evaluate comfort properties: subjective and objective evaluation. Subjective evaluation is reliable, though it is highly influenced by the impact of human differences on the test results. While objective evaluation provides quantifiable results, some of the results are less accurate, and it is recommended that both evaluation methods be used in tandem for more reliable experimental data. More research on yoga sportswear's specific design categories is needed, especially related to its functionality and specificity to the demands of yoga activities. It is clear that while the comfort properties and evaluation methods are well identified, there is no specific testing currently available to explicitly evaluate yoga sportswear. Thus, these inadequacies in yoga sportswear development warrant further exploration.

Key Words: yoga sportswear, functional attributes, comfort, evaluations, composite fabrics.

Introduction

As people have become more health-conscious in recent years, sporting activities have become a component of many people's lifestyles. The sporting goods industry is evolving due to rising health awareness, shifting channel preferences, and growing sustainability concerns. The global athletic apparel, accessories and footwear market was valued at nearly USD168 billion in 2018 and accounted for over 35% of the international sports market (Jaworek, Karaszewski, & Kuczmaraska, 2021). More recently, the global sportswear market value was USD 160.61 billion in 2020 and is projected to grow at a CAGR of 6.6% during the forecast period, from USD 170.94 billion in 2021 to USD 267.61 billion in 2028 (Insights, 2021). The underlying factors of the sportswear market increment include an increase in the number of people participating in sports, particularly working out, walking, and running, which are accessible to people of all ages (Noritake, 2017).

Sportswear often refers to clothing designed for professional sports or active sports-related activities (Venkatraman, 2015). On the other hand, Xiaofei (2021) mentioned that sportswear is no longer designed solely for athletes on the field or in sports competitions. Instead, innovations are made to make the garment more fashionable and stand out in the market.

Sportswear can be categorised into four groups: high-performance sportswear, basic sportswear, sports leisurewear and sports fashion clothing (Manshahia & Das, 2014; Stojanović & Geršak, 2019). High-performance sportswear is clothing with advanced properties that improve performance through particular functionality. In contrast, basic sportswear has a more appealing, cheaper, and trendier design, while preserving as many material attributes as possible (Chowdhury, Alam, Mainwaring, Beneyto-Ferre, & Tate, 2012; Stojanović et al., 2019). Meanwhile, sports leisurewear is a replica of high-performance sportswear sold in

higher volume at a much lower price. It is mainly worn at home when less physical activity and sweating are expected (Manshahia et al., 2014). Finally, sports fashion clothing or fashion sportswear was created with most attention paid to modern design and clothing likeability (Chowdhury et al., 2012; Stojanović et al., 2019). The classification is based on the sport they are designed for, and different functional properties will be required depending on the type of sport.

Sportswear has different functional requirements depending on the nature of the sport, climatic conditions, and amount of physical activity (Kumar, Kumar, & Rachel, 2020; Manshahia et al., 2014; Mitchell, Haskell, Snell, & Van Camp, 2005). Nevertheless, all sportswear should have basic functions such as comfort, protection, stretchability, lightweight, and dimensional stability (Govindan, 2018).

Depending on the type of sport the athlete has chosen, these functions will determine the sportswear's sweat absorption, drying rate, cooling rate, abrasion resistance and ultraviolet (UV) resistance (Manshahia et al., 2014; Stojanović et al., 2019).

The type of sports can be broadly categorised as dynamic or static exercise, depending on how intense the training is required for sports competition and the potential for bodily injury from collisions with objects, projectiles, or the ground (Levine, Baggish, Kovacs, Link, Maron, & Mitchell, 2015). Most physical activities include dynamic and static components, but dynamic exercises such as running, jumping, boxing, soccer or tennis involve intense activity during a short time (Levine et al., 2015; Manshahia et al., 2014; Mitchell et al., 2005). Meanwhile, static exercises like bowling, golf, curling or yoga are less intense and require less physical activity (Baman, Gupta, & Day, 2010; Levine et al., 2015). Understanding the type of sports will help determine the functional requirements of sportswear in enhancing athlete performance.

Despite yoga's growing popularity and potential health benefits, there is a lack of studies on the requirements of yoga sportswear. More research on yoga sportswear needs to be conducted regarding the design criteria, functional attributions, and comfort properties. So far, the discussion on sportswear is mostly about professional athlete attire. However, there is another category of athlete, which is the recreational athlete. A recreational athlete is a person who engages in physical activity but does not train for competition with the same intensity and focus as a competitive athlete (Laquale, 2009).

Examples of the type of physical activities done by recreational athletes are weightlifting, walking and gymnasium-based activities such as aerobics, dance and yoga (Doyle, Khan, & Burton, 2019). Yoga is practiced by people of all ages to stay physically fit and to be socially involved in groups, while having fun themselves (Laquale, 2009; Sharma, 2015). Even though most physical activities by recreational athletes are mainly done during leisure time, the attire aspect is still crucial in satisfying the desire for heightened aesthetics, wearer performance and wear comfort (Bruun & Langkjær, 2016). This paper intends to further discuss the appropriate sportswear design for yoga and the significance of common functional attributes influencing wearing comfort. This will help to identify the main aspects of yoga sportswear comfort properties and the method of evaluating them. This work will also benefit recreational athletes who enjoy gym-based activities, particularly yoga, and fashion designers and manufacturers by considering the essential functional qualities of sportswear.

Yoga Sportswear Design

In general, there are no specific designs made for yoga sportswear. Nevertheless, there are numerous clothing options for yoga practices, including sportswear, activewear, and the basic t-shirt, since there are many types of yoga that an individual can practice (Park, 2016). With many transitions over the years, yoga has evolved to have more than 10 variations. Some famous yoga poses today are Hatha, Vinyasa, Ashtanga, Kundalini, Iyengar and Bikram (Park, 2016; Surbhi, 2017; Wang & Szabo, 2020).

The differences between these yoga styles are movement, postures, and breathing which differ according to the mode of practice and conditions, as tabulated in **Table 1**. While the method of yoga practice varies from beginner to expert, the room condition also significantly impacts the sports attire. For instance, Bikram yoga is practised in a hot environment, which requires fabric with excellent absorption and evaporation to maintain standard and dry conditions between the skin and clothing (Lee, Jin, & Lee, 2020). Thus, clothing that allows for good evaporation during exercise in a hot and humid environment will be advantageous for comfort (Jhanji, 2021; Lee et al., 2020). Therefore, selecting the appropriate type of clothing for yoga will determine the practitioner's comfort throughout the practice.

However, choosing the appropriate sports attire for yoga could be a challenge. As claimed by Levine et al. (2015), yoga falls under static exercise since the practices are less intense and require less physical activity. In contrast, Raj (2021) has reported that yoga incorporates static and dynamic poses, where the exercise requires an intense static stretch. Moreover, yoga movements vary depending on the type of yoga practice, which can be active or passive.

For instance, there are slow-paced yoga (Hatha, Iyengar) and fast-paced yoga (Vinyasa) that require different breathing techniques and movement intensities (Park, 2016; Surbhi, 2017). Differences in movement intensity will result in different outcomes during practice, where most practitioners opt for activewear from various fashion apparel brands and different yoga-wear providers.

Table 1. Popular yoga styles and their key differences (Park, 2016)

Yoga Style	Definition	Key Difference
Hatha	Beginner yoga with basic yoga positions that combines postures with breathing.	Slow-paced yoga with a focus on breathing and controlled movement.
Vinyasa	Yoga involves powerful movements with a breathing technique called Ujjayi Breath (breathing with sound).	Fast-paced yoga requires greater breathing control with a rigorous form of movement.
Ashtanga	The oldest yoga focuses on eight traditional branches that are very athletic and physically demanding.	Repetitive by nature and follows a specific series of postures
Kundalini	Yoga incorporates movement, breathing, meditation, and chanting to develop balanced spiritual and physical practices.	Focusing on the spiritual practice of yoga.
Iyengar	Therapeutic yoga focuses on the structural alignment of each posture and sometimes involves props such as straps, blankets and blocks.	Slow-paced yoga in which poses are held for more extended periods of time with deep breaths and the use of tools.
Bikram	Hot yoga practice in a room with a temperature of nearly 40°C and 40% humidity.	Performed a specific set of 26 postures in a hot room.

Currently, numerous yoga wear providers with different focus approaches are on the market today. Professional yoga brands produce products solely for yoga practitioners, sportswear brands focus on the latest design inventions, while casual wear brands produce trendy casual clothing for everyday wear (Park, 2016). Since yoga is considered a recreational sport, these focuses are too broad, and it is up to the wearer to choose their attire, but not all sports attire suits the practice.

Apparel Elements

Most ready-to-wear (RTW) yoga clothing on the market is tightly fitted with varying construction, style, and size (Lee et al., 2020). The study investigated the current trend in yoga apparel design, where there has been significant development in sports bras, tank tops and yoga leggings. Over the years, sports bras have emerged with various designs, colours, style options, and adjustable and convertible straps (Park, 2016). Zhang, Wang and Han (2016) stated that common commercial sports bra styles are most suitable for younger and middle-aged practitioners since they vary in size and strap support. According to Zhang, Zhang, Lau, Yip, Zhou and Yu (2019), some age-friendly sports bra design criteria include an adjustable and strong elastic strap with good recovery, a higher neckline, breathable fabric, and, most importantly, adequate padding, as shown in **Fig. 1**. Significantly, the evolution of sports bras has had an impact on their functionality and wearer pressure comfort, where strap pressure is critical to providing adequate support depending on the intensity of the exercise (Erhui & Yanzhen, 2017; Zhang et al., 2016). Therefore, selecting the correct type of sports bra is essential in giving support during physical activity, as continuous and repetitive movements may result in soreness and pain.



Fig. 1. Design criteria of aged-friendly sports bra (Zhang et al., 2019)

Tank tops are yoga clothing that continues to dominate the activewear market and is practical to wear over sports bras (Cavazzana, 2021). Various designs are available on the market with different necklines, straps, fabrics and armhole lines. For example, the top's back could be intricate with straps or have a double layer of fabric with a high neck or halter neckline, as shown in **Fig. 2** (Park, 2016). Studies show that tank top design influences the wearing comfort during yoga, especially the upper body area that has more perspiration (Lee et al., 2020). Thin straps should be avoided as they put more pressure on the body and create discomfort for yoga practitioners.

Meanwhile, long or short-sleeved styles protect the shoulders and influence stretch performance during yoga exercises (Liu, Yao, Yao, & Liu, 2021). Another study showed that a simple tank top with a very long centre back and the centre front is convenient to be tucked into yoga leggings since the dimensions of the body change dramatically during yoga postures (Green, 2018a). Thus, tank top designs can be fashionable and aesthetically pleasing, but functionality should also be considered.



Fig. 2. Commercial yoga top design and yoga leggings (Lee et al., 2020)

Leggings remain a significant part of the apparel and sportswear industries that can be worn for studio and outdoor fitness activities (Groppo, 2019). There are many different types of yoga leggings on the market, and they are presented in fun, bold, colourful, and vivid patterns with prints (Park, 2016). Choosing the correct type of legging is essential as the lower limbs of the human body are drawn to stretch more since yoga maintains a static posture for certain periods of time (Wang, Yu, & Cong, 2021). Due to this, commercial leggings are mostly form-fitting and made of knitted fabric, as shown in Fig. 2, to allow the wearer a full range of motion and the ability to stretch and move freely (Stoller, 2021). The design criteria to look for in the legging style selection is the pant rise and length of pant, where high-rise leggings with a broader waistband provide more coverage and support during bending, while crop or capri length leggings are the most popular among yoga practitioners (Park, 2016). Some yoga practitioners prefer darker-coloured leggings with functional pockets (Stoller, 2021). Thus, design features and functionality are two aspects that wearers can consider when selecting yoga leggings.

Apparel Selections

Apparel selection can be determined by understanding the characteristics of common yoga apparel styles. It should also consider several major functional attributes of wear, such as garment fit, stretchability, and protection in yoga (Park, 2016). The apparel is primarily influenced by the type of yoga, as referred to in Table 2, where it is suggested that the top and bottom selection should be based on the intensity of the yoga exercise, where functionality is prioritised over fashionable design. Besides, the selection is also based on wearing comfort, where the appropriate style will enhance the wearer's performance throughout the practice.

Table 2. Suggestions of yoga attire selection based on the type of yoga

Type of Yoga	Top Selection	Bottom Selection
Slow-paced (Hatha, Iyengar)	Adequate padding sports bra with a fitted or loose tank top	Form-fitting or loose-fitting legging
Fast-paced (Vinyasa, Ashtanga, Kundalini, Bikram)	A wider sports bra that has adjustable straps with strong elastic, a higher neckline, and thicker padding. Paired with a fitted tank top with wider straps, long centre back and centre front.	Form-fitting legging, high rise, and broader waistband

Apparel Sizing

Apparel sizing is another important factor influencing the wearer's body movement during yoga besides apparel patterns. Commercial sports attire is generally produced in various sizes, but most sizing is based on a specific target population, resulting in fit variation across brands (Brubacher, 2020). Most ready-made sports apparel is based on a standard sizing system derived from the International Organization for Standardization (ISO) (Cheruiyot, 2013; Shin, Chang, & Istook, 2018). There are numerous clothing measurement systems around the world to which one can refer, but among the most important ones are international sizes, European (EU) and United Kingdom (UK) clothing size standards as tabulated in Table 3 (Bogusławska-Bączek, 2010). The standard sizing system can be as simple as one size fits all, but due to intra-individual variations in body proportions, people in the same size category may experience a different fit with the same garment. It has been reported that garment size impacts wearer comfort, particularly in hot conditions (Bragança, Carvalho, Arezes, & Ashdown, 2017; Lee et al., 2020). Ideally, yoga wear should not be too loose or too tight, as it should provide enough ease and elasticity to allow the wearer to move comfortably. Thus, choosing the right yoga fit will enhance the wearer's comfort throughout the practice.

Table 3. A comparison of women's clothing sizes system (Bogusławska-Bączek, 2010)

Country	Size													
International Sizes	XS	S		M		L		XL	XXL		XXXL			
(EU)	32	34	36	38	40	42	44	46	48	50	52	54	56	58
(UK)	-	6	8	10	12	14	16	18	20	22	24	-	-	-

Apparel Patterns

Sportswear is designed to improve overall sports performance, which is necessary to protect the body from the harsh physical environment of sports (Bruun et al., 2016). Bragança et al. (2017) have reported that sportswear should accommodate body variations over a bending joint to avoid movement restriction and discomfort, especially yoga exercises that require flexibility and movement. Appropriate sportswear design should be derived from a thorough analysis of each specific sport's patterns and body posture changes (Braganca, Carvalho, Gill, Castellucci, & Arezes, 2018; Watkins & Dunne, 2015). Examples of developments in sportswear design concepts are raglan full-sleeve t-shirt with mesh panels and open knit structure fabric designed for easy movement of the hands of tennis players, as presented in **Fig. 3(a)**. Another example is track pants with a broad elastic waistband and various features, as shown in **Fig. 3(b) and (c)**, which were designed to provide extra comfort and prevent slippage during sports (Bairagi & Bhuyan, 2021). Meanwhile, recent developments in yoga sportswear include weft-knitted seamless yoga pants designed to reduce clothing pressure on the skin, as extra threads and fabric at seams in sportswear cause discomfort (Wang et al., 2021). As a result, selecting the proper sportswear allows an individual to perform more effectively with less risk of injury and discomfort.

Understanding sportswear clothing patterns will assist in choosing the appropriate yoga clothing. According to Chowdhury et al. (2012), performance sportswear requires detailed information for garment design, since highly active sports involve speed, where aerodynamic and thermal behaviour should be considered. On the other hand, the clothing pattern for basic sportswear is much more stylish while keeping as many of the material attributes as possible (Manshahia et al., 2014). Designing sports leisurewear requires special consideration of the wearer's physiological requirements that combine aesthetics, style, comfort and functionality in a less competitive mode (Jhanji, 2021). Meanwhile, sports fashion clothing focuses on appealing designs from fashion designers, fashion houses and sports brands rather than functionality (Stojanović et al., 2019). There is no specific mention of yoga attire classification, but it is best classified under sports leisurewear, since less physical activity and sweating are expected.

According to previous research on sportswear functional attributes, sportswear should be lightweight, have good dimensional stability while sweating, and the fabric should be durable to withstand external forces during sports. Aside from that, sportswear should provide good thermal comfort by being breathable and quick drying. Furthermore, having a good fabric touch or handle that is soft and pleasant to the skin is another good functional attribute in sportswear. On the other hand, anti-odour finishing in sportswear is a reasonably common feature to include to resist unwanted odour, particularly body odour, during sweating. However, only the three functional attributes, which are garment fit, stretchability and protection are addressed in yoga wear (Park, 2016). Therefore, those qualities will be discussed in greater depth.

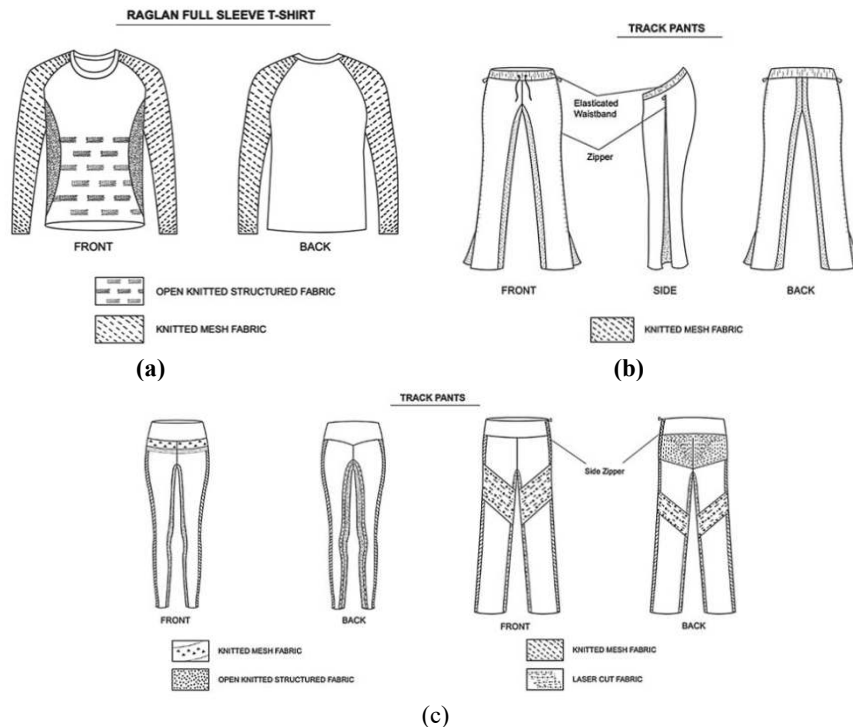


Fig. 3. Some developments in sportswear design concept; (a) full sleeve raglan t-shirt with special design fabric for high-performance sport, (b) the design concept of track pants, and (c) the design concept of track pants 2 and 3 (Bairagi et al., 2021)

Table 4. Functional attributes of sportswear and yoga wear

Functional Attributes	Sportswear (Lim et al.)	Sportswear (Kanjana et al., 2018)	Yoga Wear (Park, 2016)
Garment fit	-	-	Comfortable to put on and take off
Protection	-	-	Knees and breast support
Stretchability	-	-	Stretchable
Lightweight	Lightweight	Lightweight	Lightweight
Dimensional stability	-	Dimensionally stable even when wet	Wrinkle-free
Durability	Durable	Durable	-
Thermal comfort	Breathable, quick-dry	Optimum heat and moisture regulation, fast drying	Breathable, sweat-wicking
Touch	-	Soft and pleasant	Soft and cool
Special feature	Odour resistance, antimicrobial, waterproof	-	Anti-odour fabric

Garment Fit

Garment fit is essential in providing freedom of movement and comfort during intense workouts (Wibowo, Wijayanto, Widyastuti, & Herliansyah, 2018). According to a study on the mobility and comfort of yoga apparel, some practitioners preferred tight-fitting garments because loose silhouettes were not considered appropriate for yoga exercise due to unintended exposure when practising poses (Green, 2018b). Furthermore, loose-fit garments can prevent sweat evaporation due to increased thermal insulation (Wibowo et al., 2018). Consequently, tighter-fitting garments are preferable during yoga to keep the body warm because there is less of an air gap that prevents heat transmission (Lee et al., 2020). The amount of sweat generated depends on the type of yoga being practised. To control the body's core temperature, sweat absorption and fast-drying clothing are highly needed since sweat generation reaches 2.5L/h during an intense workout such as in fast-paced yoga, where 80% of energy is converted into heat (Manshahia et al., 2014). Thus, garment fit is a function that significantly impacts yoga wear.

Stretchability

Another critical function is stretchability, which requires yoga clothing to be flexible and stretchy enough to meet the stretching needs of the human body during exercise (Park, 2016). For instance, close-fitting tops for women, with good stretch and strong elastic recovery should be considered because they may become baggy after repeated use due to fabric growth after extension during intense body stretch (Venkatraman, 2018). Most extension occurs during bending, where the knees are the most important to focus on, and a garment with limited stretch will cause discomfort (Wang et al., 2021). Some sportswear developments include compression athletic wear (CAW), and seamless garments provide necessary compression and anatomic fit to conform to the human body's natural curves (Manshahia et al., 2014; Wang et al., 2021). However, Park (2016) mentioned that the lack of flexibility in current compression garments makes them challenging to put on and take off. Consequently, there are partition design models for compression and seamless garments to keep the stretching forces consistent across the body when moving and reduce the difference in the clothing pressure (Wang et al., 2021). Thus, stretchability in yoga wear plays an important role in adapting to different body movements.

Protection

Generally, sportswear should protect wearers against external elements and environmental extremities such as wind, sunlight, rain and snow (Jhanji, 2021). However, for yoga, those elements are not emphasised because yoga is mainly practised indoors, where body parts only require adequate protection to avoid unwanted exposure and discomfort (Park, 2016). Nevertheless, poorly designed protection in yoga wear will limit physical movements and increase the risk of functional clothing failure (Bajpai, Kapoor, & Tulsyan, 2021). According to Cavazzana (2021), unwanted exposure can be avoided by wearing full-body coverage yoga clothing since it makes the wearer feel more confident and protected. However, a high degree of body coverage clothing may keep the wearer too warm and interrupt movement. Besides, direct pressure on the knees during yoga needs more protection since repeated posture movements are likely to occur (Park, 2016). Park (2016) has also suggested the introduction of additional cushioning pads that are lightweight and detachable for the knees area to prevent discomfort. Another body part that requires protection is the chest area, which requires breast support for female yoga practitioners (Park, 2016). According to Jhanji (2021), enhanced sports bras with moulded cups and compression designs reduce breast movement and pain during moving. Thus, protection is another relevant functional requirement to look for in yoga wear.

In summary, garment fit, stretchability and protection are essential attributes for yoga besides other basic sportswear functions. Garment fit is important in providing freedom of movement and promoting heat transmission during sweating. Meanwhile, good garment stretchability is essential for providing good stretch to the wearer while stretching without restricting movements. Finally, good garment protection is crucial in protecting the wearer against any elements that cause discomfort. In this case, more protection is suggested on the knees of yoga practitioners where direct pressure occurs. We think the wrists also need support and

protection to withstand static positions and repeated postures. Thus, these functions are relevant attributes to include in manufacturing yoga sportswear.

Comfort Properties of Sportswear

In general, comfort is a neutral state in which an individual feels no pain or discomfort while wearing clothing (Kamalha, Zeng, Mwasiagi, & Kyatuheire, 2013). According to Ziemele, Šroma and Kakarāne (2018), comfortable sportswear will provide physical protection and comfort for professional and non-professional athletes during competition or training. However, the level of wearing comfort may differ between individuals even in the same physical setting, since the level of athletic exercise varies (Kamalha et al., 2013; Ziemele et al., 2018). Consequently, comfort is an important quality criterion to determine sportswear performance and wearer satisfaction based on sporting activities (Kamalha et al., 2013). There are four main aspects of comfort properties: thermo-physiological comfort, psychological comfort, skin sensorial comfort, and ergonomic comfort (Hassan, Qashqary, Hassan, Shady, & Alansary, 2012; Manshahia et al., 2014). Thus, each of the comfort properties will be discussed further below.

Thermo-physiological Comfort

Thermo-physiological comfort is influenced by the sportswear's thermal regulation and moisture transmission (Hoque, Ahmed, Zerine, & Islam, 2022; Kamalha et al., 2013). Those factors are important, especially thermal regulation, since it governs the fabric's breathability to dissipate heat to create wearable and pleasant sportswear (Das, Bhattacharjee, Kumar, & Srivastava, 2013; Hoque et al., 2022). Heat dissipation is crucial as the human body attempts to keep the core temperature at $37\pm 1^{\circ}\text{C}$ during various physical activities and climate conditions (Manshahia et al., 2014). According to Kamalha et al. (2013), sportswear should contribute to achieving an equilibrium of heat and moisture exchange between the wearer's body and the environment. There are four significant mechanisms of heat transfer to maintain thermal balance: conduction, convection, radiation, and evaporation, as shown in Fig. 4. Evaporation remains the only mode for heat loss in warmer areas where the air temperature is higher than body temperature (Manshahia et al., 2014). Besides, relative humidity is crucial to prevent thermal discomfort from dryness and body itching through sweating since yoga is mainly done indoors (Kamalha et al., 2013). Hence, maintaining a thermal balance between the body and the environment is required for thermo-physiological comfort.

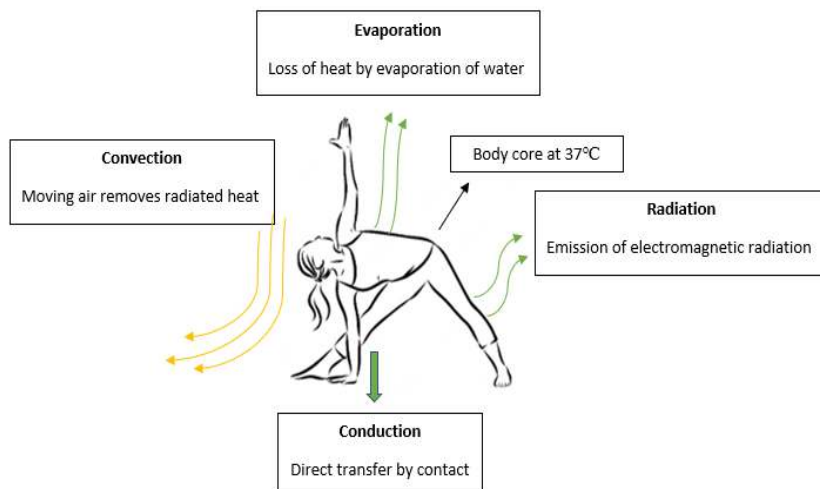


Fig. 4. Modes of heat transfer during yoga (Manshahia et al., 2014)

Moisture transmission is another factor that influences thermo-physiological comfort. Moisture transmission is involved during heat loss and is transported in both liquid and vapour phases. The three main stages of moisture transmission through the fabric are diffusion of moisture, sorption-desorption by hydrophilic, and forced convection by moving air close to the skin (Manshahia et al., 2014). A large amount of sweat during yoga will spread on the fabric and may stick to the skin, which then causes thermal discomfort (Kanjana et al., 2018). According to Manshahia et al., (2014), sportswear creates a microclimate between the body itself and its surroundings, acting as a barrier to heat and vapour transfer to maintain body core temperature, as shown in Fig. 5. However, the amount of heat released is determined by the absorbability of the sportswear material, where the final stages of moisture transmission involve a wicking process in which moisture is evaporated from the fabric and into the atmosphere through capillary wicking, leaving the skin cool (Ullah, Lejeune, Cayla, Monceaux, Campagne, & Devaux, 2022). As a result, good moisture transmission in sportswear is required to evacuate sweat from the skin to the air efficiently.

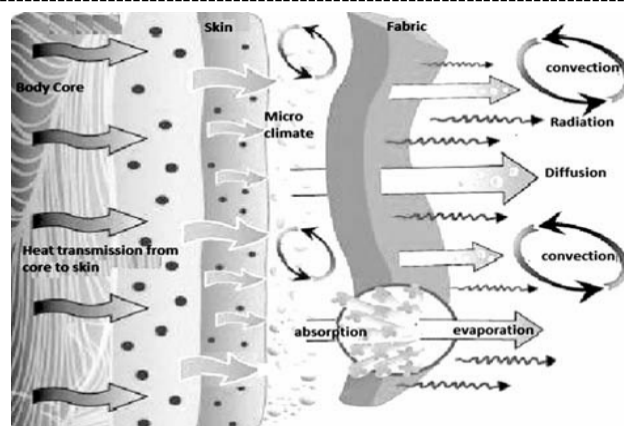


Fig. 5. Heat and moisture vapour transmission through textile materials (Manshahia et al., 2014)

Psychological Comfort

In terms of psychological comfort, an individual's psychological situation determines the wear comfort. According to Kamalha et al. (2013), psychological comfort concerns internal self-consciousness and the value of life as it relates to satisfying oneself within the options available. The decision has a few psychological attributes, such as economic, environmental, historical, social status, cultural, individual and group aspects (Kamalha et al., 2013; Ziemele et al., 2018). However, Hassan et al. (2012) have reported that individual and group aspects are the most effective, including personal preferences, fashion, and ideology. Besides, the wearer's past clothing experience, choices for fit and the desire for comfortable yoga wear affect psychological perceptions (Kamalha et al., 2013).

The perceptions are closely related to psychological values such as self-esteem, where some wearers feel more comfortable with clothing that offers more coverage, especially during yoga (Kamalha et al., 2013; Luna Mora & Berry, 2021). As a result, psychological values may differ from person to person for what they perceive to be related to their clothing and comfort preferences.

Skin Sensorial Comfort

Skin sensorial comfort is a mechanical sensation caused by direct contact of clothes to the skin, where the tips of one's fingers are enough to feel the softness and roughness of the fabric (Hassan et al., 2012; Kanjana et al., 2018; Manshahia et al., 2014). Aside from that, tactile sensations such as smoothness, stickiness, and stiffness can be felt by touching the cloth, where the skin is highly sensitive to mechanical stimuli (Kamalha et al., 2013).

Scientifically, the skin is the largest organ of the human body and is more prone to feel some sensorial discomforts that can affect yoga performance, especially during twisting and bending (Manshahia et al., 2014). Sensorial discomfort can come from rough and stiff surface fabric that may cause skin abrasion and wet garment clinging caused by sweat residue stickiness on the skin (Kanjana et al., 2018). Moreover, prickliness and itchiness will reveal discomfort in the form of pain and affect yoga performance (Kamalha et al., 2013). According to Manshahia et al. (2014), selecting well-fitted and low-friction sportswear can help to reduce skin sensorial discomfort. Thus, selecting a soft fabric on the skin is essential to prevent skin discomfort.

Ergonomic Comfort

The ergonomic comfort of clothing is essential to support the wearer during different activities (Teyeme, Malengier, Tesfaye, Ciesielska-Wrobel, Haji Musa, & Van Langenhove, 2021). The main requirements for ergonomic wear comfort in sportswear are freedom of movement and maintaining body shape (Kanjana et al., 2018; Teyeme et al., 2021).

Those requirements are primarily defined by the garment's fit design and pattern construction and can also be influenced by the material elasticity or stretchability (Hassan et al., 2012; Manshahia et al., 2014; Teyeme et al., 2021). Due to the high degree of body movements repeatedly performed from the yoga poses shown in Fig. 6, yoga sportswear should not restrict these movements.

Otherwise, discomfort will be created due to undesired garment pressure on the body (Teyeme et al., 2021). Elastic fabric is commonly used in tight-fitting shorts to prevent discomfort, providing the desired shape and size while allowing for adequate body movement (Manshahia et al., 2014). Hence, ergonomic comfort is essential for yoga practitioners because it can improve their performance and prevent injuries during movements.



Fig. 6. Examples of yoga poses (Norozpoursġgaroodġ, 2023)

Evaluation Method of Comfort Properties

Generally, clothing comfort is highly subjective, but wear comfort can be assessed using subjective and objective methods (Manshahia et al., 2014). Most studies of sports clothing comfort are based on subjective feeling evaluation methods (Xiaofei, 2021). However, some researchers prefer objective evaluation methods, where laboratory testing provides better accuracy of wearing comfort (Kamalha et al., 2013). According to Xiaofei (2021), each evaluation method has its advantages and disadvantages. Therefore, both subjective and objective evaluation methods will be discussed further.

Subjective Evaluation Method

The subjective evaluation of sportswear comfort refers to the assessment made by the wearer based on their psychological feelings. The wearing comfort is determined by physical indicators of clothing style and material and by many psychological factors that affect the wearer's feelings and sports performance (Xiaofei, 2021). They stated that many expressions for the subjective feeling of comfort in sportswear fall into a few sensation index categories, such as heat and humidity, tactile, wearable, and composite. However, comfort sensation in sportswear is mainly from the heat and humidity category that defines discomfort, as shown in **Table 5**. Moisture comfort is the most crucial contributor to evaluating comfort during yoga since intense sweating is expected from fast-paced yoga (Manshahia et al., 2014). From the table, common comfort expressions described by past researchers are stickiness, dampness, and non-absorption of sweat. These expressions are essential to determine suitable sportswear for yoga according to the nature of sports. As a result, the wearer can express the comfort sensation that determines discomfort through subjective evaluation.

Table 5. Functional attributes of sportswear and yoga wear

Past Researchers	Sportswear Comfort sensation
Manshahia et al. (2014)	Clammy, clingy, sticky, damp, heavy
Suganthi, Senthilkumar and Dipika (2017)	Stiffness, stickiness, non-absorbance, dampness, clamminess, coldness, roughness, scratchiness
Xiaofei (2021)	Heat and warmth, humidity, a feeling of muggy, cool, sticky, and sweat flow, non-absorption of sweat, smoothness

The psychological scale and comparative sorting methods are common subjective evaluation methods (Xiaofei, 2021). The psychological scale method employs specific numerical values to quantify the subjective comfort level, with the intensity scale representing least to most comfortable (Suganthi et al., 2017). Parameters such as stiffness, stickiness, and dampness are usually determined from the wearer's subjective feelings using a few odd numbers level with no mandatory standard. However, the evaluation method has relatively high requirements on the subjects, and the formal test can only be performed after a calibration test. Comparative sorting methods, on the other hand, evaluate sportswear by pairwise comparison, with the highest number of points given by the wearer indicating the best comfort and the lowest scoring indicating the worst. Although no method can quantitatively assess clothing comfort, they are helpful due to their low cost and high repeatability (Xiaofei, 2021). Thus, subjective evaluation is highly influenced by the impact of human differences on the test results, but it is also reliable.

Objective Evaluation Method

Objective evaluation is a method that uses equipment to ensure consistency and precision of results (Kamalha et al., 2013). The objective evaluation usually standardises the working environment and conditions

before assessing the sports comfort of sportswear. Most objective evaluations are done in a laboratory environment which can be subdivided into physical and physiological evaluation methods. The physical evaluation method primarily measures changes presented by the wearer, such as range and angle of human body joint movement, human activity efficiency bound by sportswear and sportswear deformation characteristics during exercise. Meanwhile, the physiological evaluation method measures the changes in a series of physiological indicators such as human body temperature, heart rate, and sweat volume caused by the restriction of sportswear during exercise, which regulates the body core and skin temperature (Xiaofei, 2021). The objective methods for each aspect of comfort properties can differ depending on the type of evaluation. Therefore, the objective methods for each main aspect of the comfort properties of sportswear will be discussed further.

Various objective methods can determine thermo-physiological comfort properties. For instance, the heat flux sensing principle using PERMETEST assists in determining moisture vapour and heat transmission through the fabric. Meanwhile, the sweating-guarded hot plate (SGHP) can simulate sweating skin and determines fabric moisture vapour resistance by measuring evaporative heat loss in steady-state conditions. Another innovative method to evaluate combined heat and moisture transfer is the thermal manikin. Two types of manikins are available: viz dry manikin and sweating manikin, which measure dry heat flow and simulate the perspiring human body, respectively. The sweating manikin can independently control thermal zones at various locations to measure heat and moisture transmission from various parts of the human body (Manshahia et al., 2014). According to Švecová, Lopourová and Halatová (2020), these objective method instruments are essential to observe sportswear's comfort properties, since sportswear's thermos-physiological comfort properties are substantially lower during a dry state due to the absorption of sweat.

Meanwhile, moisture transmission evaluation can be measured by the amount of water vapour that passes through a substance or material over a given time, which is referred to as the moisture vapour transmission rate (MVTR/WVTR). Fan, Wang, Kan, Promlawan, Changmuong and Mongkholrattanasit (2020) reported that the moisture transfer of fabric is closely related to the drying speed of clothing. One of the tests is the Water Vapor Permeability Test, which evaluates the ability to release water vapour from the wetter surface to the dry surface of clothing. The test is performed in accordance with the international measurement standard (ASTM E96), which evaluates the steady flow of water vapour in a specific unit of time through a unit area of a body at standard temperature and humidity at each surface ($\text{g/m}^2/24\text{hr}$) (Fan et al., 2020). According to Lam, Wang, Kan, Mongkholrattanasit, Wangyen and Sujarittanonta (2021), the water vapour transmission rate is greatly influenced by fabric characteristics such as fabric weight and thickness, as shown in **Table 6**. Lower fabric density allows more vapour to pass through the pores between yarns, resulting in a higher water vapour transmission rate from the body to the surrounding environment (Fan et al., 2020; Wang et al., 2021). As a result, higher water vapour transmission values have better fabric evaporation ability, hence resulting in faster drying.

Table 6. Functional attributes of sportswear and yoga wear (Fan et al., 2020)

Brand	Fabric composition	Fabric Weight (g/m^2)	Fabric Thickness (mm)	MVTR ($\text{g/m}^2/24\text{hr}$)
Adidas	61% recycled polyester & 39% polyester	128.41	0.33	50.32
Nike	85% polyester & 15% cotton	130.61	0.30	55.47
Laishilong	100% polyester	142.76	0.29	61.49
Nike	84% Polyester & 16% Spandex	161.00	0.54	65.30

Therefore, it is recommended that good breathable fabric is used for yoga sportswear because it dries faster and allows more vapour to pass through the pores between the fabric. This will prevent the wearer from feeling discomforts, such as stickiness, dampness and clamminess while wearing the sportswear during yoga. For instance, it is best to wear sports bras and tops that are made from lightweight and breathable materials such as polyester, since it will wick away moisture from the skin while providing the right amount of support (Venkatraman, 2018). In addition, stretchy fabrics like polyester and spandex are ideal for yoga leggings because they are non-restrictive and allow the wearer to move freely while performing yoga poses correctly. Meanwhile, cotton is much more suitable for indoor uses where less sweating is expected, such as slow-paced yoga, since the fabric will absorb moisture quickly but is less suitable for a high-intensity workout. Thus, wearing breathable sportswear with a high vapour transmission rate is suggested during yoga.

On the other hand, the skin's sensorial comfort depends on friction from the fabric skin and the surface roughness (Manshahia et al., 2014). There are several methods to evaluate the sensorial comfort properties of sportswear. According to Utkun (2021), the fabric handle is commonly used to evaluate sensory sensitivity to the sense of touch based on physical stimuli. However, fabric handles are difficult to define precisely since they are based on a subjective perception of sensations and require years of experience (Gonca Özçelik, Nilgün, & Gamze Süpüren, 2012). Therefore, the an objective evaluation method for fabric handles is often used, which is the Kawabata Evaluation System (KES-F) which was developed in Japan by Professor Kawabata and the Hand Evaluation and Standardization Committee (HESC) (Manshahia et al., 2014; Utkun, 2021). Researchers have

been using the KES-F to investigate the tactile properties of fabrics used for various purposes. One of the purposes of KES-F is to measure the surface properties of sportswear under wet conditions, as the presence of moisture during sports can alter the perception of roughness. It has been reported that the occurrence of moisture from skin wetness tends to increase friction and fabric clinging, which results in wear discomfort or skin injuries (Tang, Chau, Kan, & Fan, 2018). Although the system is reliable for evaluating skin sensorial comfort, the instrument requires experts to interpret the resulting data.

The ergonomic comfort of sportswear can be evaluated by measuring the clothing pressure and other related sensation. According to Xiaofei (2021), clothing pressure is exerted on the human body due to skin elongation caused by exercise. Skin elongation happens when the human body flexes and deforms during exercise, and the clothing pressure can be analysed through the rotating level of joint movements and motion performance of the sportswear (Manshahia et al., 2014). For this purpose, direct and indirect measurements can evaluate the clothing pressure influencing ergonomic comfort during sports. Direct measurement requires the use of a clothing pressure measuring device such as an Air pack pressure sensor and I-Scan pressure mapping sensor to measure the clothing pressure value on the wearer directly, which are simple to use and intuitive, but easily affected by noise due to body movement (Teyeme et al., 2021).

Meanwhile, the arch compression, soft dummy, and theoretical calculation methods are examples of indirect measurement methods (Xiaofei, 2021). Besides, video-based motion analysis is another method for assessing ergonomic comfort to evaluate sportswear's impact on body motion (Manshahia et al., 2014). Although objective methods provide quantifiable results, some are far from the accurate perception of the ergonomic comfort (Teyeme et al., 2021). Thus, direct and indirect measurement methods should be combined to provide more accurate and reliable experimental data for ergonomic comfort.

Conclusions

More research on yoga sportswear needs to be conducted regarding its specific requirements. We have reviewed the appropriate yoga sportswear design based on the type of yoga and its intensity, though there is a wide range of sportswear options available. Yoga practitioners commonly choose sports bras, tank tops, and yoga leggings with the design criteria of good stretching and recovery, breathable fabric, form-fitting, adequate support, and body coverage. It is strongly suggested that the selection of yoga attire should be based on the type of yoga, either Hatha (steady) or Vinyasa (energetic). The recent development of form-fitting seamless yoga leggings is a good step in the right direction, as it is designed to reduce clothing pressure on the skin and prevent discomfort, especially for Vinyasa. Regarding functional attributes, garment fit, stretchability, and protection are also essential for yoga activities, besides other basic sportswear functions such as being lightweight, having good dimensional stability, durability, and acceptable thermal comfort.

Furthermore, our review found that the four aspects of comfort, namely the thermo-physiological, psychological, skin sensorial, and ergonomic, have not been well studied in yoga sportswear. Thus, we strongly suggest that designers should focus more on the comfort aspects for upcoming yoga sportswear development, since comfort evaluation via subjective and objective methods are available and reliable. In conclusion, there is a need for a fresh approach to develop functional yoga sportswear, other than focusing on its fashion aspects alone. We also recommend that more seamless yoga attire designs to be made for sports bras and tank tops and that the selection of appropriate fabric for the attire is evaluated in the laboratory to determine the subjective and objective wearing comfort.

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