7-1-2022

An Expert Assessment On Playspace Designs And Thermal Environments In A Canadian Context

Daniel J. Vecellio

Jennifer K. Vanos
Arizona State University

See next page for additional authors

Authors

Daniel J. Vecellio, Jennifer K. Vanos, Eric Kennedy, Heather Olsen, and Gregory R.A. Richardson

Urban Climate 44 (2022) 101235

Contents lists available at ScienceDirect

Urban Climate

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

An expert assessment on playspace designs and thermal environments in a Canadian context

Daniel J. Vecellio[a,*,1], Jennifer K. Vanos[b], Eric Kennedy[c,d], Heather Olsen[d], Gregory R.A. Richardson[e]

[a] *Climate Science Lab, Department of Geography, Texas A&M University, College Station, TX, USA*
[b] *School of Sustainability, Arizona State University, Tempe, AZ, USA*
[c] *Department of Biomedical Engineering, Bucknell University, Lewisburg, PA, USA*
[d] *National Program for Playground Safety, University of Northern Iowa, Cedar Falls, IA, USA*
[e] *Climate Change and Innovation Bureau, Health Canada, Ottawa, ON, Canada*

ARTICLE INFO

Keywords:
Child
Hot temperature
Ultraviolet rays
Climate change
Urban health
Play
Playground

ABSTRACT

Playgrounds are a hub for child play and concerns that may impact children's play there may hinder their health and well-being. Extreme temperatures can increase risks in children of sunstroke, burns from playground surfaces, and exposure to ultraviolet radiation. Despite health risks from extreme heat to children, existing playground design standards around the world, including in Canada, make little-to-no mention of how to design playgrounds for thermal comfort, particularly in summer. To help fill this gap in the Canadian context, several organizations collaborated to develop guidance for thermally comfortable playgrounds in Canada. As part of this project, an online survey was administered to 55 experts with diverse professional backgrounds, largely from Canada and the United States, to determine how thermal comfort is viewed in playground design and safety. Survey results showed agreement among experts that thermal comfort receives low or no priority in playground design but should be prioritized or considered alongside other safety factors in relevant playground safety guidelines and standards. The results of this survey not only helped inform the 2020 publication of a Thermal Comfort annex to the CSA Group's *Children's playgrounds and equipment* standard (CAN/CSA Z614) but could also help inform future research and practice globally.

1. Introduction

Play, which involves engagement in an activity for enjoyment, is a fundamental means through which children develop physically, socially, emotionally, and intellectually (Murray et al., 2013). Playgrounds are a central hub for children's outdoor play. Moreover, concerns are increasing about diminished play opportunities and their impact on physical activity levels and obesity in children in western industrialized nations (Alexander et al., 2012). Therefore, any characteristics that may impact children's play, including at playgrounds —such as unsafe environmental conditions, polluted air, persistent heat and sunlight, or chemicals—may hinder children's health and well-being (Cohen, 1989).

* Corresponding author at: 422 Biobehavioral Health Building, University Park, PA 16802, USA.
E-mail address: djv5030@psu.edu (D.J. Vecellio).
[1] Current affiliation: Center for Healthy Aging, Pennsylvania State University, University Park, PA, USA.

https://doi.org/10.1016/j.uclim.2022.101235
Received 26 February 2022; Received in revised form 31 May 2022; Accepted 5 July 2022
Available online 14 July 2022

Current playground guidelines for safety focus on the prevention of serious injuries (ASTM, 2017), yet injury rates remain stagnant (Keays and Skinner, 2012; Macarthur et al., 2000; O'Brien, 2009), even with numerous new surface and equipment standards devised (ASTM, 2017; CPSC, 2010). While many of the current standards aim to protect user safety for blunt force trauma, many do not explicitly protect against extreme thermal exposures, particularly extreme heat—an often overlooked health risk for children in playspaces (Hyndman, 2017; Vanos et al., 2016). Some standards (e.g., (Standards Australia (2017), Canadian Standards Association (2020) state the importance of sun and shade considerations in design, yet do not relate these guidelines to extreme heat injury or thermal comfort. Thermal comfort is defined as a person's satisfaction with their thermal environment, which is based on both physiological and psychological properties (ASHRAE, 1966; Fanger, 1970; Parsons, 2014), and results when an individual has no preference to be warmer or cooler (Fanger, 1972; Fanger, 1970). More thermally comfortable spaces promote outdoor park space use (Chen et al., 2015), specifically in recreational spaces in warmer seasons. In practice, thermal comfort is affected by six variables: four environmental (ambient air temperature, humidity, sun exposure, and wind speed) and two behavioural (clothing insulation and metabolic rate). While numerous models exist to integrate these variables into a human energy balance based on outdoor design for adults (Graham et al., 2017) few studies have assessed children's thermal comfort in frequently-visited environments, such as playgrounds (Antoniadis et al., 2020; Vanos et al., 2017a, 2017b).

Children are particularly vulnerable to hot ambient environments and heat stress compared to adults (Berry et al., 2014; Kovats and Hajat, 2008). Children are more susceptible than adults to sunburns and burn injuries because of their less adaptive behaviour (e.g., knowledge and sunscreen use), high intermittent exposures, slower reaction time to stimuli, and more sensitive skin (ISO13732, 2005; Volkmer and Greinert, 2011). Preventing over-exposure to ultraviolet (UV) radiation and extreme heat, while ensuring that there are safe outdoor spaces for adequate play, are vital to promoting children's long-term health and reducing risk (USDHHS, 2014). Over-exposures to heat and sunlight present near-term issues, such as heat stress, illness, and sunburn, or thermal burns (Berry et al., 2014; Vanos, 2015). Further, long-term chronic health problems from childhood sun exposure may not present themselves until later in life, such as adult skin cancer (American Cancer Society, 2017; Dennis et al., 2008). It is estimated that children who get five or more sunburns double their chances of deadly melanoma later in life (Skin Cancer Foundation, 2021). Increases in melanoma incidence rates within Canada warrant the need to reduce UV exposures (O'Sullivan et al., 2019).

Despite the known health risks to children from heat in general, little formal data is available on the specific number of heat-related injuries and illnesses from overexposure to heat at playgrounds (e.g., burns). Ford et al. (2011) reported 14 severe burn cases in children from exposure to playground surfaces across the US, with 9 of the 14 cases being second- or third-degree burns; but the authors suspected that less extreme burns are much more frequent and go unreported. While no published data is available for Canada, the media has reported the dangers of hot play equipment on the health of children, including articles about the dark rubber mats under play equipment reaching 81 °C, hot enough to burn a child (Silva, 2018), as well as reports about children suffering second degree burns after sliding down a metal slide in Toronto (Pelley, 2017) and in Calgary (Southwick, 2015). These types of environmental health risks at playgrounds are particularly important in the context of climate change. The increase in 'very hot' days in many cities worldwide because of climate change is likely to magnify existing heat-related risks to children in outdoor spaces. For example, in Canada, the focus of this study, the numbers of extremely hot days (maximum temperature of $\geq$30 °C) in the country's six largest cities by population – Toronto, Montreal, Vancouver, Calgary, Edmonton and Ottawa – are projected to more than double by 2050 (Prairie Climate Center, 2018).

There are movements in many countries to green schoolyards to support nature-based play. For example, Paris's "Oasis" Project is greening 700 schoolyards, totaling 197 acres, with changes expected to green 1/5th of the city and positively impact the surrounding urban environment. Non-profits in the US are transforming asphalt-covered schoolgrounds into green spaces that improve child well-being, play, and learning (Green Schoolyards America, 2020). In Canada, several non-profits and government agencies issue grants of varying sizes to increase vegetation levels in schools across the country (e.g., Evergreen, 2021; Government of Quebec, 2021; Tree-Canada, 2021). These school ground greening efforts, which include the removal of hard surfaces and the planting of vegetation, can simultaneously promote higher levels of physical activity by creating spaces that are more conducive to longer periods of safe and active play (Cosco et al., 2014). Research has shown that these green spaces in playgrounds create opportunities for vigorous play while spaces with concrete or asphalt could contribute to sedentary outdoor activity (Dyment et al., 2009). This can cause difficulties in urban communities where green space can be limited and playgrounds are some of the only available spots for safe, active play. An increase in childhood obesity (Babey et al., 2012; Ogden et al., 2016) and decrease in the amount of play globally warrants greater attention to accessible, free, and safe outdoor play (Murray et al., 2013; Ramstetter et al., 2010). A focus on urban design adaptation (Table 1) to limit temperature extremes, particularly heat, are important considerations to ensure adequate play and physical activity,

Table 1
Climate adaptation types from the Intergovernmental Panel on Climate Change (IPCC, 2014) that can be applied to children's health in playgrounds to maintain healthy lifestyles.

Adaptation type	Relevant examples
Physiological	Children acclimatization to warmer weather at the start of the heat season. This process can take up to 2–4 weeks.
Behavioural	Children learning to make appropriate clothing choices, learning about the feelings of heat stress, wearing a hat, taking water breaks.
Infrastructure	Incorporating increased shade (both natural and built) in playgrounds; focus on creating park cool islands to increase playability; using less heat retaining and heat conductive playground equipment
Technological	Air conditioning to cool off indoors; mister systems; heat-health warning systems; monitoring weather conditions within a playground (i.e., local microclimate conditions) for decision making by owners/operators and users.

yet aspects related to extreme heat and mitigation of sun exposure are rarely, if at all, considered in playground safety guidelines in North America, and minimally in playground design.

Novel studies have also assessed the use and design of school and playground microclimates, particularly in Australia (Pfautsch et al., 2020; Pfautsch and Wujeska-Klause, 2021), Europe (Boldemann et al., 2011), and North America (Blanchard, 2013; Cosco et al., 2014). These studies point to considerations of heat and sun exposure as factors in the type and amount of safe play. Despite the known health benefits to children of cool, comfortable and green playgrounds, existing playground design standards around the world, including in Canada, make little to no mention on how to design playgrounds for thermal comfort in summer (ASTM, 2017; CPSC, 2010). To help fill this gap in the Canadian context, several organizations collaborated to develop guidance for thermally comfortable playgrounds in Canada via the CSA Group's *Children's playgrounds and equipment* standard (CAN/CSA Z614). As part of the project to integrate thermal comfort into the Canadian standard, an online survey was administered to 55 experts with diverse professional backgrounds from Canada and the United States to determine how thermal comfort is viewed in playground design and safety. In surveying and garnering insight from experts from Canada and across the globe specializing in landscape architecture, playground designers, manufacturers, and engineers, child health researchers, and educators, we specifically set out to determine: 1) how environmental factors are considered in playground design, 2) how priorities in playground design have changed over time, and 3) what individual factors guide the incorporation of thermal comfort into playground design. While the focus of this manuscript is on Canada, many of the findings can be applied to countries with similar playground safety guidelines and climates. The need for continued data collection, as well as quantification of the effects of thermal comfort and child play, are also summarized.

2. Methods

2.1. Survey participants

To understand how experts involved in various aspects of playspace design and safety view the interrelationship between thermal comfort and other playground safety and hazards, a multi-sectoral and interdisciplinary survey was conducted. The authors, in partnership with the Thermal Comfort Task Force of the CSA Group, invited a diverse list of experts to collect professional opinions, judgement, and experiences on the matter of child health and well-being during play, playground environmental conditions, thermal comfort, playground design, and user experience. To accomplish this, a convenience sampling method was used. Each survey respondent was recruited based on several factors. Given the geospatial importance of collecting information relative to the Canadian environment, respondents were identified based on both topical expertise, as well as those with background and experience within the context of Canada and across Canadian geographical regions. Overall, the survey respondents consisted of experts with diverse backgrounds from a variety of Canadian geographical regions, along with additional experts with an international background. Both grey and academic literature were also reviewed to identify content experts.

Eighty topical experts were invited to complete the survey, with fifty-five individuals participating, a response rate of 69%. The final group of respondents was comprised of diverse content experts from different climates with backgrounds in climate and environmental scientist (11 respondents); landscape architects, urban planners, designers (14); playground manufacturer and installation (11); child health and well-being (7); and educators, consultants, or risk mangers (12) (see Table 2). The survey was provided in Qualtrics and left open for 3 weeks in March 2019. All survey methods were reviewed and approved by Bucknell University's Institutional Review Board (IRB# 1819–076) on behalf of the University of Northern Iowa and Arizona State University.

2.2. Survey

A survey was developed to collect opinions and background on four topics: (1) design priorities on playgrounds, (2) thermal comfort factors on playgrounds, (3) heat/cold mitigation strategies to improve thermal comfort related to safety and (4) updated playground safety standard development. The survey questions, which contained both multiple-choice questions and open-ended responses, were informed by concepts related to thermal comfort from both academic (e.g., scientific, peer review, books) and grey (e.g. newspapers, magazines, books, websites, policy guides, technical reports) literature. Specific information in these four main topic areas included:

- Playground priorities – identifying relative priorities that environmental factors receive versus other design factors (particularly safety)

Table 2
Topical expert summary, responses by background.

Expertise/background	Survey invitation	Survey responses (% response rate)	Canadian context (% of respondents)
Climate/Environmental Scientist	18	11 (61.1%)	9 (81.8%)
Landscape Architect, Urban Planning, Indep. Designer	21	14 (66.7%)	14 (100%)
Manufacturer, Installation, Supplier	14	11 (78.6%)	11 (100%)
Child Health and Well-being	12	7 (58.3%)	6 (85.7%)
Education, Consultant, Risk Management	15	12 (80%)	10 (83.3%)
TOTAL	80	55 (68.8%)	50 (90.9%)

- Thermal comfort factors – identifying the perceptions of the relative importance or contributions of different factors to the idea of thermal comfort on playgrounds
- Mitigation strategies – identifying the priority levels for different playground design factors that are most commonly associated with thermal comfort management
- Standard development – collecting the perceptions of individuals on how standards can and should address the topic of thermal comfort at playgrounds, which may also be useful in highlighting areas of the most consensus and most persuasive (but not commonly known) suggestions.

3. Results

Survey results focus on the combined consideration of the thermal and radiative environment in concert with technical playground design, including safety, structural integrity, and accessibility. Together, these constitute planners' choices that influence the thermal comfort of the users of the space. Consideration is given to both the construction of new playgrounds and the retrofitting of current playgrounds. While designers cannot account for the subjective nature of the users' thermal comfort (clothing choice, experience, water consumption) or physiology (height, weight, metabolic rate), survey results show that the physical landscape, design, and local climate regime should be considered in tandem to create thermally comfortable playgrounds for children and families.

3.1. Environmental design priority rankings in children's playspaces

Survey results show a disconnect between the importance of considering environmental factors when siting a playground and its equipment versus how often these considerations are realized in its implementation (Fig. 1). Seventy-nine percent (79%) of survey participants felt that environmental factors, such as weather or air and chemical pollution, were either extremely important or very important to children's playspaces and equipment. However, 77% of the respondents indicated that environmental factors had not received the same amount of priority as other safety factors in the planning and development of playspaces (Fig. 1). These other safety factors, presented in the CSA Group standards, included playground equipment materials, structural integrity, surfacing, inspection, and maintenance. Broken down further, 83% of respondents reported that the surrounding thermal environment was given less or significantly less priority than these other safety factors while 4% thought they were given equal priority and 13% were uncertain.

Strong agreement was also present among respondents when asked if environmental conditions influenced the choices of children and families' visitation to a playspace, with 83% (45/54) of respondents stating that the environment influenced these decisions. Of these 45 respondents, weather conditions were at the forefront of their reasoning in both the cold and the warm seasons. The impact of weather on the thermal condition of the playspace, as well as its influence on air quality in and around the playspace, were noted repeatedly in written responses, with examples provided below.

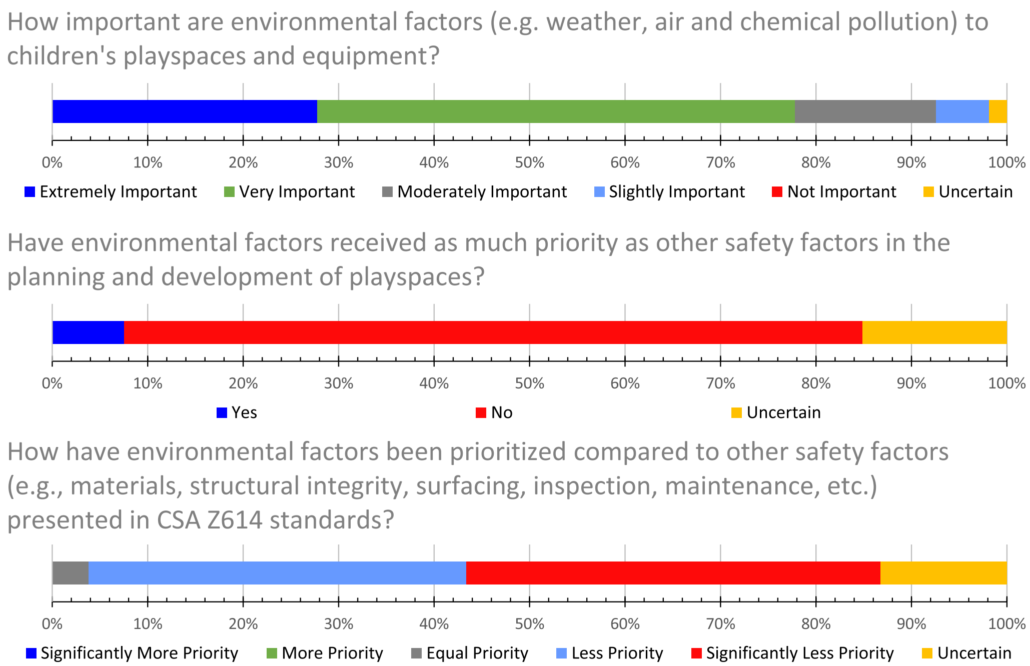

Fig. 1. Perceptions of importance and realized prioritization of environmental factors in playground design.

"I think a lot of people make decisions about using outdoor recreational spaces, such as playgrounds, based on the weather conditions. During bad weather (wind, snow, cold), people will seek a space that is protected from the wind and allows the sun in, and some air flow. In the heat, people will seek a location that is cooler due to shading and/or vegetation. Overall for the entire population, weather plays a large role in recreational activities. I think playgrounds are a space that can be designed in a way to protect users from extremes." – Environmental Scientist/Engineer.

"I suppose heat and humidity may play a role as would the opposite of cold in one's interest or perhaps medical capacity to visit an outdoor park environment. One susceptible to temperature extremes may avoid being outside for extended periods of time. Also surrounding elements like airborne smog from neighbouring factories or facilities may affect one's ability to cope with an outdoor play environment." – Playground Sales and Distribution.

3.2. *Priorities for playground design: past versus aspirational*

Fig. 2 illustrates respondents' perceptions on what has, in the past, been a priority within playground design. While it is notable that there were no playground design issues rated as receiving *high-priority* attention, 68% of the expert respondents shared that the safety and structural integrity of equipment have been a *priority* in playground design. A cluster of second-tier issues related to fencing, proximity to hazards, maintenance, surfacing, and impact attenuation received similar *priority* scores (41% on average) across expert respondents. These factors, along with accessibility and child supervision, were accounted for in the original CSA Group standards. However, related to children's thermal comfort within playgrounds (last four rows of Fig. 2), the availability of play water features and drinking water fountains, as well as playspace shade, have received *low* or *no priority* in past playground design (Fig. 2).

Aspirational priorities of water and shade were closely related to comfort in the warm season based on responses in Fig. 3. These factors are shown to have received *low priority* in past planning and design efforts, with shade receiving the least priority (65% of responses of *low* or *no priority*) historically. The majority of respondents (72% and 70%) acknowledged that the availability of water features for play and drinking water, respectively, have been given either *low priority* or were *not prioritized* during the playground design process in the past. However, for water play features, only 18% of respondents stated that such play water features should

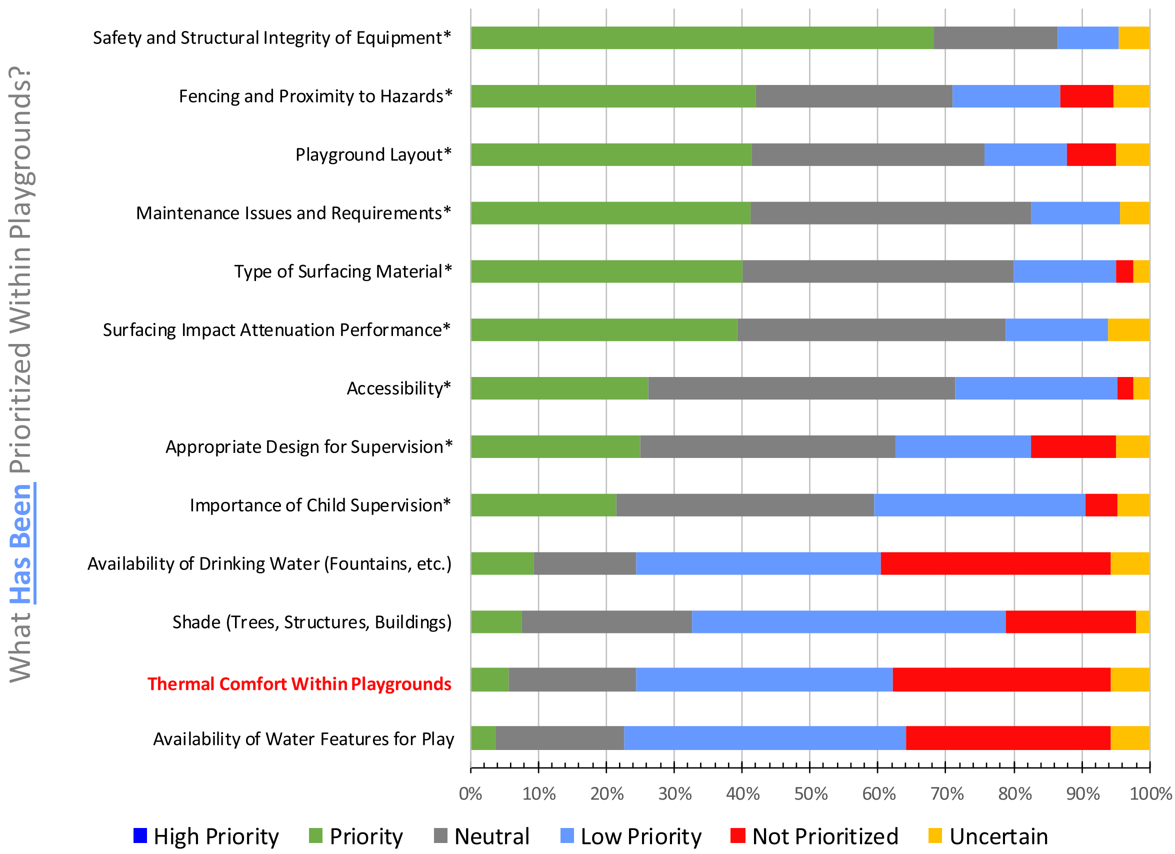

Fig. 2. Perceptions of past prioritization of a variety of playground design issues.

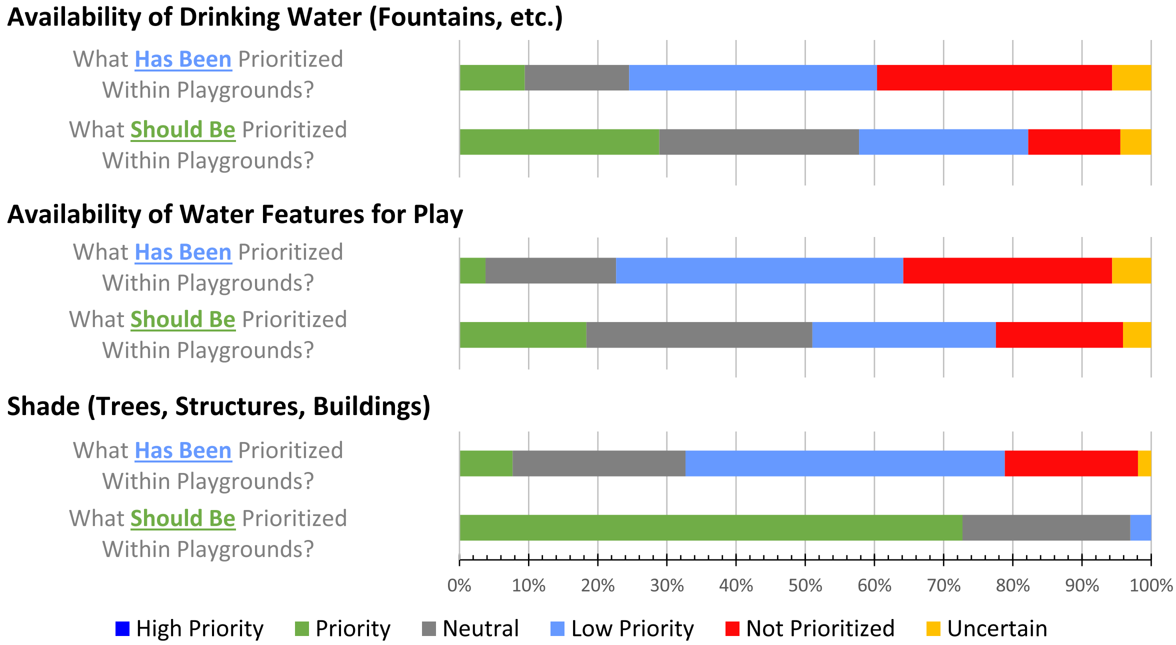

Fig. 3. Perceptions of the past (*has been*) vs. aspirational (*should be*) prioritization for the availability of water (drinking and play features) and shade (natural or manufactured) at playgrounds.

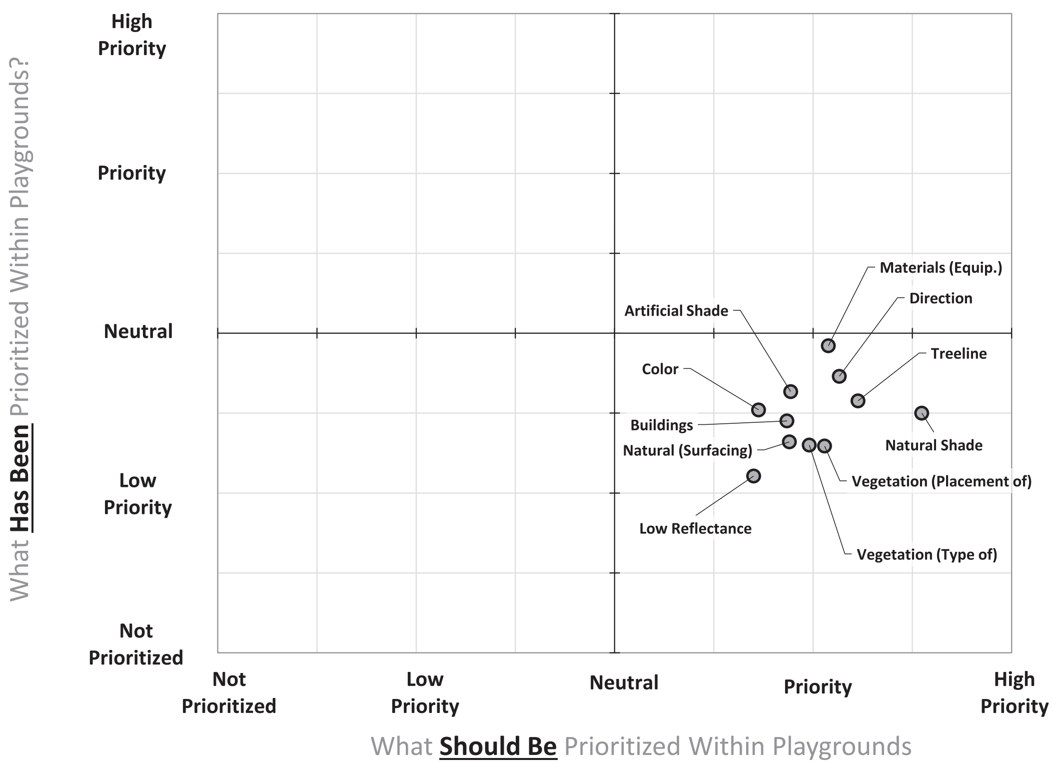

Fig. 4. A perception map detailing expert responses regarding their response to the historical (has been) versus aspirational (should be) prioritization of commonly used design elements and features for thermally comfortable playgrounds. Data comprising the vertical axis are shown in Fig. 2.

receive priority in aspirational designs. Respondents suggested additional consideration be devoted to these water features where applicable, although their seasonal window of usefulness in Canada is more limited than other intentional design issues, such as shade and surfacing. Similarly, only 29% of respondents supported future prioritization of water fountains, which may be due to budgetary constraints impeding past design.

> *"As a designer/ project manager it would be nice to make all listed facets as a top priority. Unfortunately, the projects' budget is a large factor in what gets implemented into a playspace. So, as a result, certain items (e.g. drinking fountain), although may have been included in the Concept Stage, get deleted during the implementation stage"* – Landscape Architect / Site Design.

Compared to water features, the prioritization of the availability of shade at playgrounds demonstrated the greatest disparity between past and aspirational design practices (Fig. 3). Only 8% of respondents indicated that considerations of shade had received *priority* in past playground designs. A further 65% indicated that shade had received *low priority* or *no priority* in past playground designs. In contrast, 73% of respondents indicated that shade should be given a *priority* in future/aspirational playground design.

Fig. 4 displays a perception map visually linking past and aspirational priorities surrounding the importance of various playground features that are known to affect thermal comfort. All design features and elements sit below the neutral axis on the vertical scale, indicating that these elements and features have historically been given *low priority* in playground design. Further, all features and elements are perceived to require *priority* in playground development, with little overall differentiation between elements. Results showed natural shade received slight aspirational *higher priority* relative to the other features and elements.

Experts were asked to provide suggestions for how to design for thermally comfortable playgrounds. Shade and/or water features were included within the content of **every** open-ended response. All respondents who chose to answer the open-ended question agreed shade and water aid in mitigation of extreme temperatures. A number of experts gave examples of different types of shade (e.g. shade sails, natural, fabric structures, canopy, buildings, photovoltaic structures, and awnings) and water features (e.g. splash pads, water play areas, and misting posts.

> *"In order to create effective shade (through a health equity lens), shade audits of these spaces must take place."* – Child Health & Wellbeing Specialist.

> *"Utilization of materials with low solar reflectance, location of hardscapes, utilization of natural shade. Shade is great with [Landscape Architects] that know what they are doing for municipal projects but is an afterthought for schools, daycares, resorts and other privately owned playspaces. Different customer types have different levels of knowledge regarding thermal comfort ranging from a lot to none at all."* – Manufacturer, Installation, Supplier.

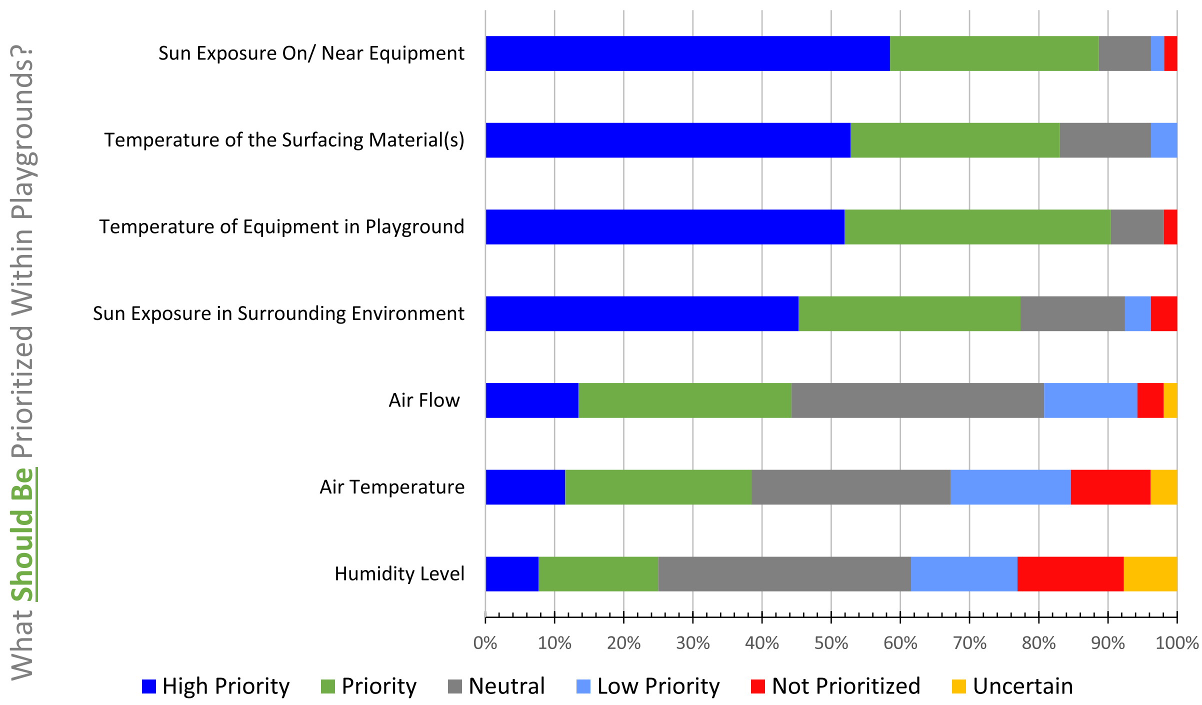

Fig. 5. Perceptions of how the four environmental components should be prioritized in playground design.

> "*We don't need shade everywhere, but we should invest in shade where activity happens. Agencies responsible for playspaces should reimagine their properties' distribution of shade on their property to prioritize places where children play.*" – Landscape Architect, Urban Planning, Independent Designer.

3.3. Individual variables related to thermal comfort for design

Familiarity of concepts relating to thermal comfort, not simply limited to playscape environments, was extensive in the survey population. Forty-six respondents (85%) noted they were *very or somewhat knowledgeable* about thermal comfort, and all participants stated to have some knowledge on the topic. Further, 70% of the respondents indicated that thermal comfort had been given either *low priority* or had been *not prioritized* during past playground design, and merely 6% stated that considerations of thermal comfort in design decisions had been a *priority*. However, 85% of those surveyed stated that they have considered or encountered outdoor environments that had design features to help mitigate extreme temperatures and facilitate thermal comfort. In their open-ended responses, most respondents noted measures taken against extreme heat, which included natural or structural shading, the inclusion of water in the playspace through misters, and cool surfacing for playground equipment. The few respondents who also saw measures taken against extreme cold mentioned creating windbreaks to block prevailing wintertime winds that flow into the playspace, either through walling or vegetation.

Perhaps taking note of thermal comfort implementations they had encountered, 49% of the experts indicated that intentional design to improve thermal comfort throughout the year was an aspirational priority, while 21% of respondents indicated that thermal comfort should receive *low* or *no priority* in the future. Solar radiation exposure was given highest consideration as a future priority in playground design (Fig. 5), Respondents shared that sun exposure in the surrounding environment (77%), temperature of equipment (90%), temperature of the surfacing material (83%), and sun exposure on or near the playground equipment (89%) should receive *priority* or *high-priority* with regard to thermal comfort management. Less priority was given to air flow (wind) (44%), air temperature (38%), and humidity levels (25%) for management of these components.

In their open-ended responses, a number of respondents correctly noted that such ambient weather conditions are largely uncontrollable, which corresponds to those variables receiving the lowest scores in prioritization (Fig. 5). Any changes will occur at the

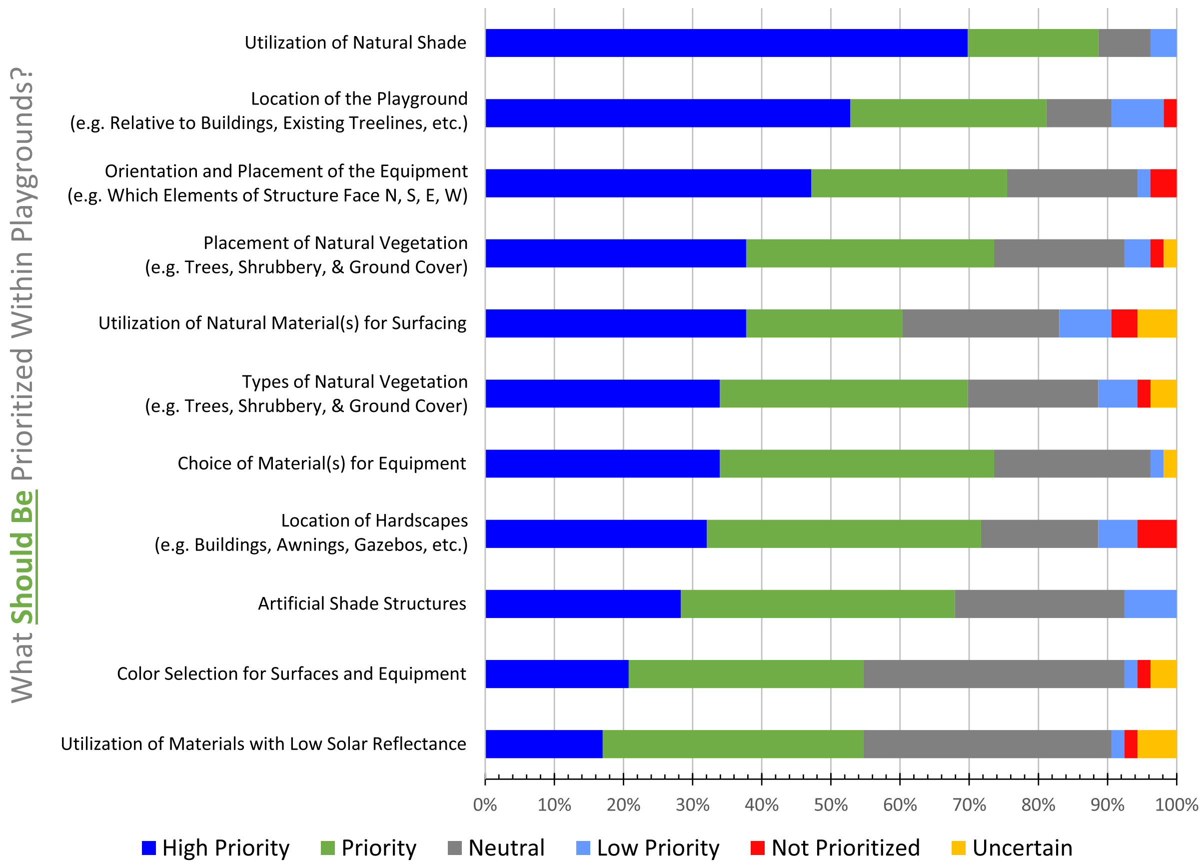

Fig. 6. Expert responses on future priority for common design elements and features for thermally comfortable playgrounds.

microscale and mitigating measures could create other unwanted responses. One such response summarized this as follows:

> *"Temperature and humidity - while I'm sure we would love to be able to control these, it's very difficult to do to so. We may be able to change our temperature by a few deg[rees] F[ahrenheit] (through natural shading and surfaces), which is great, but we have a lot more power to change the radiation levels within the microclimate, which in turn can help reduce these air temperatures (only a bit). This is due to wind mixing up the air. Humidity is very tough too, and we have to accept that by putting in more green space, we may slightly increase the amount of vapor in the air, which is why ensuring adequate wind flow in a space in the summers is important."* – Environmental Scientist/Engineer.

To accomplish these microscale modifications, experts were asked how commonly used thermal comfort design elements should be prioritized in future playground design (Fig. 6). At least 75% of expert respondents rated *three* design considerations as *priority* or *high priority*, all pertaining to a radiative load reduction: utilization of natural shade (89%), playground siting near existing buildings or treelines for shade (81%), and the orientation and placement (e.g., which elements of structures face north, south, east, and west) of equipment (75%). The importance of greening playground areas in the future was also apparent as the placement and type of natural vegetation received 74% and 70% *priority/high priority* scores, respectively. Overall, there is an agreement and understanding that all aspects of thermal comfort must be addressed in planning of future playgrounds as all design considerations received *priority/high priority* scores of at least 55%.

4. Discussion

The findings from the expert survey show that designing for thermal comfort has to date not been prioritized in playground designs. In comparison with more structural aspects of playspaces, such as structural integrity of equipment, safe landing spots for falls, and proper maintenance of equipment, the experts surveyed recommend more attention be given to implementing strategies for mitigating the effects of extreme temperatures on playspace users. This is especially important in the context of climate change as Canada is warming at a rate double the global average (Bush and Lemmen, 2019), but will also continue to experience months of cold weather as well. Most respondents focused their responses to survey questions on mitigating extreme heat (as opposed to cold) at playgrounds, which led to near-unanimous agreement on the need for future shade and water implementation at playspaces. Research on heat and UV mitigation through shade use in summertime is increasingly prevalent in the literature (Downs and Parisi, 2009; Middel et al., 2016; Middel and Krayenhoff, 2019). However, mid-latitude climates require adequate sun in the spring, autumn, and winter for warmth and Vitamin D synthesis (Miyauchi and Nakajima, 2016), thus a balanced approach is optimal, with deciduous trees within playspaces that support both shade in the summer and sun in the late fall, early spring and winter.

Experts noted that priority in future playground design should focus around reducing sun exposure causing extreme surface temperature during the summertime by utilizing natural shading mechanisms. Creating new shading opportunities or taking advantage of current site layouts with current or new shade to reduce radiative load on children and equipment is the most effective way to improve the thermal comfort of playspace users in the warm season (Vanos et al., 2017a, 2017b). By utilizing nearby tall vegetation and hardscapes in conjunction with an understanding of the sun's position in the sky, playground equipment and open playspaces can be positioned in locations where ample shade is provided during peak hours of use of the day in warm seasons without requiring additional built shade. However, overcoming barriers to shade provision – such as budget, space constraints, and maintenance and operational concerns – can limit the ability to provide adequate shade during these peak hours (Cimino et al., 2021). Moreover, the availability of water (for play and drinking) and shade may improve children's heat safety and the usage of a space, particularly in hot summertime conditions, which often coincide with peak playground usage. Water features and drinking water fountains can increase cooling and safety during hot summertime conditions by lowering air temperature and providing water to evaporate from skin, which can keep body temperatures down and limit dehydration (e.g., Morris et al., 2020). Shade and water availability can be considered in concert with each other for optimal play.

Table 3
Intentional strategies that can improve (↑) or reduce (↓) thermal comfort, based on changing the main factors of sun exposure, wind/ventilation, temperature, and relative humidity.

Feature	Category	Warm season			Cold season		
		Sun	Wind	Temper-ature	Sun	Wind	Temper-ature
Shade	Deciduous	↑	–	↑	↑	–	↑
	Coniferous	↑	↑[a]	↑	↓	↑[a]	–
	Manufactured	↑	–	↑	↓	–	↓
Ground-level Vegetation	All	↑	–	↑	–	↑	↑
Lighter Color Materials	Surface	↓[b]	–	↑	↑[b]	–	↓
	Equipment	↓[b]	–	↑	↑[b]	–	↓

A dash (–) indicates no well-known or significant relationship between that mitigation and its influence on thermal comfort. For example, planting of deciduous trees in summer can improve thermal comfort by decreasing sun exposure and air temperature, but can have a slight effect in increasing humidity.

[a] Focus on blocking prevailing winter winds and not blocking summer winds.

[b] Due to reflection of sunlight.

The survey also addressed how design and materials across playspaces affect thermal comfort of the users (see Table 3). For example, after sun exposure and surface temperatures, wind was the most important environmental parameter to be changed via design (Fig. 5), followed by air temperature and humidity. Wind is a significant predictor of thermal comfort in the cold season (hence the wind chill effect) and can be blocked using design strategies. As a result, for design decisions around sun and wind, it would be advantageous for sun path diagrams and wind roses, respectively, to be used (Brown and Gillespie, 1995). These microclimatic considerations are imperative to increasing the thermal comfort of the playspace, creating temperature, wind, and sunlight changes on the micro-scale that improve thermal comfort, as there is no design component that can change the large-scale ambient weather. Based on our survey results, with proper guidance, these considerations can take place in the early stages of planning by taking steps in planning to (1) identify times of expected peak usage, (2) conduct shade studies, (3) evaluate predominant local-scale wind patterns, and (4) determine site access to water before making firm decisions on layout and accessibility (Kennedy et al. ., 2021).

Different considerations in how to increase the thermal comfort of a playground may be needed when designing new playgrounds versus retrofitting existing ones. A majority of the survey respondents noted that the CSA Group's playground safety standard needed to make this distinction as existing playspaces were designed to a previous standard which didn't include thermal comfort guidance. Once again, survey participants stated that budgets will be critical as more money available is likely to facilitate new construction. This clean slate with more financial flexibility allows for playspace designers to consider a larger set of thermal comfort factors from the beginning. Examples include the consideration of ambient environment and climate, the results of shade audits, and the amount of landscaping and planting of new vegetation that can be done. Public funds may not be available for retrofits and outside fundraising could be needed to make changes to increase thermal comfort. Various opinions were stated in dealing with thermal comfort deficiencies in existing playgrounds, ranging from the need to retrofit immediately to a 5–10-year grace period before being grandfathered into the standard to a full exemption from the standard. However, if short-term thermal comfort measures are not implemented, playspaces may be under-utilized or not used at all, making any money put towards their intermediate maintenance not focused on thermal comfort an objective loss. Compromises between safety, affordability, and efficacity will need to be taken into account in situations of playground retrofits.

The survey raised various research gaps. First, there is a need for prescribing general best practices in design (yet not overly prescriptive, as stated by one expert) for different climate zones for improved thermal comfort throughout the year, yet also focused on times when playground usages are highest (e.g., summer). Second, there should be a focus on enhanced efforts in studying the thermal comfort of children in different climate and geographical contexts as much of the current research is only applicable to adults. Third, future research and application should help to broaden the scope of what is considered "safety" from the more traditional playground hazards to environmental health considerations including thermal comfort. For example, researchers could investigate innovations in safe equipment and surfacing materials that both reduce fall injuries while also maintaining thermal safety. Finally, developing effective tools and resources for a range of people – including planners and community developers, health officials, school administrators, early childhood professionals, schools, playground designers, parks departments, and urban planners – to advance the design of cool, protected, and green playgrounds in Canada and beyond.

5. Conclusions

Outdoor play is critically important for the mental and physical development of children. Creating safe and comfortable spaces for play in a way that enhances usability and "playability" of a space is imperative to support such development. Many playground safety standards, including the previous iteration of the CSA Group's *Children's playgrounds and equipment* standard (CAN/CSA Z614) only included considerations for structural integrity, safety, and accessibility of equipment and the playspace itself. However, given the increasing threat of extreme heat on human health because of climate change, it's increasingly important for thermal comfort to be considered in playground design. In the process of updating CAN/CSA Z614, Canadian and international experts involved in different facets of playground design and child health were surveyed to gather information on their experiences with past priorities and future needs to ensure thermal comfort and safety for users of these spaces.

The survey results provide insight into how thermal comfort is viewed in playground design and safety. There was wide agreement across the spectrum of researchers, design experts, and industry manufacturers that future playground safety standards should include a focus on creating thermally safe and comfortable playspaces. Playspace-scale implementation was the focus of most answers considering it is very hard to change large-scale, ambient weather and climate factors. Reducing radiative exposure with natural or artificial shade and increasing water presence in playspaces, both for drinking and playing, received high favourability from respondents, though the need for nuance in execution was noted due to budgetary concerns. Site surveys of new and existing playgrounds should be done to consider how linkages can be created between traditional design advice regarding playground and equipment layout or accessibility and new thermal comfort provisions such as radiative gain through shading and spaces to plant new vegetation which can provide localized temperature effects via albedo and latent cooling. Attempting to integrate a larger number of safety policies through a smaller number of design initiatives through design synergy has the ability to increase thermal comfort, improve child's play, save money, and promote the short- and long-term health of playspace users.

Survey responses noting the disconnect because past playspace design strategies and aspirational needs and wants given budgetary constraints show that playground safety is a complex issue. Working together, national, regional and local governments in coordination with health practitioners, manufacturers, and academic researchers could advance research and advocacy efforts to improve playground use and safety related to children's thermal exposures. While the focus of this manuscript is on Canada, the survey was international in scope and many of the findings can be applied to countries with similar playground safety guidelines.

Funding

This project was supported by the Standards Council of Canada's Standards to Support Resilience in Infrastructure Program and with guidance from the Climate Change and Innovation Bureau at Health Canada.

Acknowledgement of material from published report

Some of this material was taken from the following project report, and permission has been obtained to reprint it: Kennedy, E.A., Olsen, H.A., Vanos, J.K. (2020). Thermally comfortable playgrounds: A review of literature and survey of experts. Standards Council of Canada. https://www.scc.ca/en/about-scc/publications/general/thermally-comfortable-playgrounds (English) | https://www.scc.ca/fr/notre-organisme/publications/general/le-confort-thermique-des-terrains-de-jeu (French). This report was prepared for the Standards Council of Canada. All major contributors of this work were contacted and agree to this publication.

CRediT authorship contribution statement

Daniel J. Vecellio: Conceptualization, Validation, Writing – original draft, Writing – review & editing. **Jennifer K. Vanos:** Conceptualization, Methodology, Validation, Writing – original draft, Writing – review & editing, Funding acquisition. **Eric Kennedy:** Conceptualization, Methodology, Validation, Formal analysis, Data curation, Writing – review & editing, Visualization, Funding acquisition. **Heather Olsen:** Conceptualization, Methodology, Validation, Formal analysis, Data curation, Writing – review & editing, Supervision, Funding acquisition. **Gregory R.A. Richardson:** Conceptualization, Writing – review & editing, Supervision, Funding acquisition.

Declaration of Competing Interest

We have no conflicts of interest to report.

Acknowledgements

The authors would like to thank Kayla Dustin, Anna Bourke, and Brooke Brown, former students at the National Program for Playground Safety, for their help with the analysis of the survey data. Thanks to Marla Desat (Standards Council of Canada) and Alexandra Rutledge (Health Canada) for their contributions to the broader project. We also thank all experts who took the time to complete the survey to inform this research.

References

Alexander, S.A., Frohlich, K.L., Fusco, C., 2012. Playing for health? Revisiting health promotion to examine the emerging public health position on children's play. Health Promot. Int. 29, 155–164. https://doi.org/10.1093/heapro/das042.
American Cancer Society, 2017. Skin Cancer Prevention and Early Detection [WWW Document]. https://www.cancer.org/content/dam/CRC/PDF/Public/6930.00.pdf (accessed 5.1.22).
Antoniadis, D., Katsoulas, N., Papanastasiou, D.K., 2020. Thermal environment of urban schoolyards: current and future design with respect to children's thermal comfort. Atmosphere (Basel). 11, 1144.
ASHRAE, 1966. Thermal Comfort Conditions. ASHRAE Standards 55–66, New York.
ASTM, 2017. Standard Consumer Safety Performance Specification for Playground Equipment for Public Use. ASTM F1487–17.
Babey, S., Wolstein, J., Diamant, A., Bloom, A., Goldstein, H., 2012. Overweight and Obesity among Children by California Cities - 2010 (Los Angeles).
Berry, P., Clarke, K., Fleury, M.D., Parker, S., 2014. Human Health in Canada in a Changing Climate: Sector Perspectives on Impacts and Adaptation. In: Warren, F.J., Lemmen, D.S. (Eds.). Government of Canada, Ottawa, ON, pp. 191–232.
Blanchard, S., 2013. Improving* Hermal Comfort in Windsor, ON. Assessing Urban Parks and Playgrounds, Windsor, ON.
Boldemann, C., Dal, H., Mårtensson, F., Cosco, N., Moore, R., Bieber, B., Blennow, M., Pagels, P., Raustorp, A., Wester, U., 2011. Preschool outdoor play environment may combine promotion of children's physical activity and sun protection. Further evidence from southern Sweden and North Carolina. Sci. Sports 26, 72–82.
Brown, R.D., Gillespie, T.J., 1995. Microclimate Landscape Design: Microclimatic Landscape Design: Creating Thermal Comfort and Energy Efficiency. John Wiley & Sons, Inc, NewYork.
Bush, E., Lemmen, D.S., 2019. Canada's Changing Climate Report. Government of Canada = Gouvernement du Canada.
Canadian Standards Association, 2020. CSA Z614:20 Children's Playground Equipment and Surfacing.
Chen, L., Wen, Y., Zhang, L., Xiang, W.-N., 2015. Studies of thermal comfort and space use in an urban park square in cool and cold seasons in Shanghai. Build. Environ. 94, 644–653.
Cimino, A., McWhirter, J.E., Papadopoulos, A., 2021. Made in the shade: a qualitative study of factors impacting shade provision at outdoor public parks. Int. J. Environ. Health Res. 1–13. https://doi.org/10.1080/09603123.2021.1977257.
Cohen, C.P., 1989. United nations: convention on the rights of the child. Int. Leg. Mater. 28, 1448–1476.
Cosco, N.G., Moore, R.C., Smith, W.R., 2014. Childcare outdoor renovation as a built environment health promotion strategy: evaluating the preventing obesity by design intervention. Am. J. Health Promot. 28, S27–S32.
CPSC, 2010. Handbook for Public Playground Safety. Bethesda, MD.
Dennis, L.K., Vanbeek, M.J., Freeman, L.E.B., Smith, B.J., Dawson, D.V., Coughlin, J.A., 2008. Sunburns and risk of cutaneous melanoma: does age matter? A comprehensive meta-analysis. Ann. Epidemiol. 18, 614–627.
Downs, N.J., Parisi, A.V., 2009. Ultraviolet exposures in different playground settings: a cohort study of measurements performed in a school population. Photodermatol. Photoimmunol. Photomed. 25, 196–201.
Dyment, J.E., Bell, A.C., Lucas, A.J., 2009. The relationship between school ground design and intensity of physical activity. Child. Geogr. 7, 261–276.
Evergreen, 2021. Evergreen Canada Projects [WWW Document]. https://www.evergreen.ca/our-projects/school-board-collaborations-services/ (accessed 11.11.21).
Fanger, P.O., 1970. Thermal Comfort. Danish Technical Press, Copenhagen.
Fanger, P.O., 1972. Thermal Comfort New York.

Ford, G., Moriarty, A., Riches, D., Walker, S., 2011. Playground Equipment: Classification & Burn Analysis (Worcester).
Government of Quebec, 2021. Mon Climat Ma Sante [WWW Document]. http://www.monclimatmasante.qc.ca/carte-des-projets-contre-les-ilots-de-chaleur.aspx (accessed 11.11.21).
Graham, D.A., Vanos, J.K., Kenny, N.A., Brown, R.D., 2017. Modeling the effects of urban design on emergency medical response calls during extreme heat events in Toronto, Canada. Int. J. Environ. Res. Public Health 14. https://doi.org/10.3390/ijerph14070778.
Green Schoolyards America, 2020. Outdoor Spaces are Essential Assets for School Districts' COVID-19 Response Across the US.
Hyndman, B., 2017. Heat-Smart'schools during physical education (PE) activities: developing a policy to protect students from extreme heat. Learn. Commun. J. Int. J. Learn. Soc. Context. (Special Ed.) 21.
IPCC, 2014. Impacts, adaptation, and vulnerability. Part B: regional aspects. In: Barros, V.R., Field, C.B., Dokken, D.J., Mastrandrea, M.D., Mach, K.J., Bilir, T.E., Chatterjee, M., Ebi, K.L., Estrada, Y.O., Genova, R.C., Girma, B., Kissel, E.S., Levy, A.N., MacCracken, S., Mastrandrea, P.R., White, L. (Eds.), Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge Univesity Press, Cambridge, United Kingdom and New York, NY, USA, p. 688.
ISO13732, 2005. ISO 13732: Ergonomics of the Thermal Environment—Methods for the Assessment of Human Responses to Contact with Surfaces. Geneva, Switzerland.
Keays, G., Skinner, R., 2012. Playground equipment injuries at home versus those in public settings: differences in severity. Inj. Prev. 18, 138–141.
Kovats, R.S., Hajat, S., 2008. Heat stress and public health: a critical review. Annu. Rev. Public Health 29, 41–55.
Macarthur, C., Hu, X., Wesson, D.E., Parkin, P.C., 2000. Risk factors for severe injuries associated with falls from playground equipment. Accid. Anal. Prev. 32, 377–382.
Middel, A., Krayenhoff, E.S., 2019. Micrometeorological determinants of pedestrian thermal exposure during record-breaking heat in Tempe, Arizona: introducing the MaRTy observational platform. Sci. Total Environ. 687, 137–151.
Middel, A., Selover, N., Hagen, B., Chhetri, N., 2016. Impact of shade on outdoor thermal comfort—a seasonal field study in Tempe, Arizona. Int. J. Biometeorol. 60, 1849–1861. https://doi.org/10.1007/s00484-016-1172-5.
Miyauchi, M., Nakajima, H., 2016. Determining an effective UV radiation exposure time for vitamin D synthesis in the skin without risk to health: simplified estimations from UV observations. Photochem. Photobiol. 92, 863–869. https://doi.org/10.1111/php.12651.
Morris, N.B., Jay, O., Flouris, A.D., Casanueva, A., Gao, C., Foster, J., Havenith, G., Nybo, L., 2020. Sustainable solutions to mitigate occupational heat strain–an umbrella review of physiological effects and global health perspectives. Environ. Health 19, 1–24.
Murray, R., Ramstetter, C., Devore, C., Allison, M., Ancona, R., Barnett, S., Gunther, R., Holmes, B.W., Lamont, J., Minier, M., 2013. The crucial role of recess in school. Pediatrics 131, 183–188.
O'Brien, C.W., 2009. Injuries and investigated deaths associated with playground equipment, 2001–2008. Report by the US Consumer Product Safety Commission. https://www.cpsc.gov/s3fs-public/pdfs/playground.pdf, pp 1-24.
Ogden, C.L., Carroll, M.D., Lawman, H.G., Fryar, C.D., Kruszon-Moran, D., Kit, B.K., Flegal, K.M., 2016. Trends in obesity prevalence among children and adolescents in the United States, 1988-1994 through 2013-2014. Jama 315, 2292–2299.
O'Sullivan, D.E., Brenner, D.R., Villeneuve, P.J., Walter, S.D., Demers, P.A., Friedenreich, C.M., King, W.D., Team, C.S, 2019. Estimates of the current and future burden of melanoma attributable to ultraviolet radiation in Canada. Prev. Med. (Baltim) 122, 81–90.
Parsons, K., 2014. Human Thermal Environments: the Effects of Hot, Moderate, and Cold Environments on Human Health, Comfort, and Performance. CRC Press.
Pelley, L., 2017. Why Does Toronto Allow Metal Slides? Mom Wants Answers after 2-Year-Old Suffers Serious Burns.
Pfautsch, S., Wujeska-Klause, A., 2021. Guide to Climate-Smart Playgrounds: Research Findings and Application.
Pfautsch, S., Rouillard, S., Wujeska-Klause, A., Bae, A., Vu, L., Manea, A., Tabassum, S., Staas, L., Ossola, A., Holmes, K., Leishman, M., 2020. School Microclimates. Sydney, Australia.
Prairie Climate Center, 2018. Climate Atlas of Canada. Winnepeg, MB.
Ramstetter, C.L., Murray, R., Garner, A.S., 2010. The crucial role of recess in schools. J. Sch. Health 80, 517–526.
Silva, E., 2018. Dealing with the Dangers of Hot Playground Equipment.
Skin Cancer Foundation, 2021. Sunburn & Your Skin [WWW Document]. https://www.skincancer.org/risk-factors/sunburn/ (accessed 5.10.22).
Southwick, R., 2015. Slides at Calgary Park Close after Burning Backsides. Calgary Herold.
Standards Australia, 2017. AS 4685.0:2017 Playground Equipment and Surfacing: Development, Installation, Inspection, Maintenance and Operation.
TreeCanada, 2021. Greening Canada's School Grounds [WWW Document].
USDHHS, 2014. The Surgeon General's Call to Action to Prevent Skin Cancer. Washington, D.C.
Vanos, J., 2015. Children's health and vulnerability in outdoor microclimates: a comprehensive review. Environ. Int. 76, 1–15.
Vanos, J.K., Middel, A., McKercher, G.R., Kuras, E.R., Ruddell, B.L., 2016. Hot playgrounds and children's health: a multiscale analysis of surface temperatures in Arizona, USA. Landsc. Urban Plan. 146 https://doi.org/10.1016/j.landurbplan.2015.10.007.
Vanos, J., Herdt, A., Lochbaum, M., 2017a. Effects of physical activity and shade on the heat balance and thermal perceptions of children in a playground microclimate. Build. Environ. 126, 119–131.
Vanos, J.K., Herdt, A.J., Lochbaum, M.R., 2017b. Effects of physical activity and shade on the heat balance and thermal perceptions of children in a playground microclimate. Build. Environ. 126 https://doi.org/10.1016/j.buildenv.2017.09.026.
Volkmer, B., Greinert, R., 2011. UV and children's skin. Prog. Biophys. Mol. Biol. 107, 386–388. https://doi.org/10.1016/j.pbiomolbio.2011.08.011.