Building and Environment 179 (2020) 106915

Contents lists available at ScienceDirect

Building and Environment

journal homepage: http://www.elsevier.com/locate/buildenv

Care provider assessment of thermal state of children in day-care centers

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ARTICLE INFO

Keywords:
Day-care center
Children
Care providers
Thermal sensation
Thermal state

ABSTRACT

Young children are vulnerable to extreme temperatures due to their physiological and anatomical characteristics and behavioural dependability. The latter is a relatively unexplored area. Therefore, the current study investigated the skin temperature as a proxy of the thermal state of children and care providers in day-care centers, the ability of the care providers to estimate the thermal state of the children and their knowledge on this topic. Results from 104 children (<four years old) and 58 care providers recruited from six different day-care centers in winter and summer in the Netherlands show that there was no difference in thermal state between the children and care providers. A significant relation ($p < 0.05$) was found between skin temperature of the care providers and thermal sensation in winter and summer, but not for the skin temperature of the children and the assessed thermal sensation score of the children by the care providers ($p > 0.05$). Furthermore, many care providers had difficulties naming symptoms of heat illness and the care providers with ≤5 years work experience had a lower knowledge level of thermoregulation than care providers with >5 years work experience. It is recommended to train care providers in thermal assessment, in particular novice care providers that have less knowledge on this topic.

1. Introduction

The ability of children to cope with extreme temperatures is limited compared to adults, mostly due to physiological and anatomical characteristics [1–4]. For instance, since the sweat glands of children are not fully developed until after puberty, children have lower sweat rates and increased risk of thermal injury in the heat [5,6]. In addition, children have a larger body surface area-to-mass ratio in comparison to adults, which can lead to a faster and greater change of body temperature in an environment with extreme temperatures [2]. Moreover, metabolic rate is higher due to low mechanical efficiency [1]. Consequently, physical activity at the same intensity results in a greater heat production in children compared to adults [5,7].

Besides thermoregulatory differences between children and adults, behavioural dependability is another characteristic that results in enhanced vulnerability in the youngest (<four years old) children. Children of this age group depend on their parents or care providers to get dressed and may have difficulties expressing discomfort regarding temperature sensation or thirst [8,9]. Furthermore, children generally engage in more physical activities outdoors than adults [2]. Previous research has shown that significantly more children were brought into the emergency department during days with high ambient temperatures compared to days with lower ambient temperatures [10]. To reduce these risks, parents and care providers should be well informed about the effect of the environmental conditions on children's health and wellbeing and what precautionary measures are appropriate, as this most likely avoids morbidity and mortality in children due to the heat [3]. Knowledge about this is even more relevant since more extreme weather events, like heat waves, occur due to climate change [11].

In the last few years the number of children below the age of four attending a day-care center has increased significantly in the Netherlands. In the first quarter of 2019, 338,000 children went to a day-care center at least one day a week, which resulted in 88,000 more children than in 2015 [12]. Care providers are responsible for the wellbeing of these children in day-care centers and with the rise in attendance and the increased prevalence of extreme weather conditions,

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https://doi.org/10.1016/j.buildenv.2020.106915
Received 1 February 2020; Received in revised form 24 March 2020; Accepted 21 April 2020
Available online 28 April 2020
0360-1323/

it is imperative that the care providers are well informed about the thermoregulation of children, potential temperature related risks and how to act in the event of a temperature related illness. In particular, if a child has symptoms of heat illness immediate action is required [13]. However, to the authors' knowledge, there are no studies investigating thermal stress in children in day-care centers or studies that have examined the knowledge of the care providers on this topic. Furthermore, the buildings of day-care centers in the Netherlands are often old and the quality of the indoor climate is insufficient [14]. Whilst a few studies have investigated the effect of indoor air quality, including temperature, on respiratory health of the children in day-care centers [15–19], these studies did not perform any physiological measurements. This study therefore investigated the effect of ambient temperature on the thermal state of children in day-care centers in summer and winter in the Netherlands. Thermal state in this study is defined by the mean skin temperature (T_{sk}) of four different body locations, since previous studies have shown that T_{sk} is a good predictor of thermal sensation [20,21]. The ability of the care providers to estimate the thermal state of the children was examined, as well as the knowledge of the care providers about thermoregulation in children, temperature related illnesses and precautionary measures to reduce cold and heat exposure. It is hypothesized that the thermal state of the children is different than the thermal state of the care providers due to the difference in thermoregulation and surface to volume ratio, as well as differences in behaviour during the day. Further, it is hypothesized that care providers cannot correctly estimate thermal state of the children, but that due to sufficient knowledge and experience appropriate actions are taken within day-care centers.

2. Methods

Ethical approval

The current study was approved by the ethical committee of the Faculty of Behavioural and Movement Sciences of the Vrije Universiteit Amsterdam in the Netherlands (VCWE-2017-183). Informed consents were conducted according to the declaration of Helsinki and signed by the parents of the children to approve participation of their child, as well as by the care providers to approve their own participation.

2.1. Participants

Children and care providers were recruited from six participating day-care centers across the Netherlands (Arnhem, Assen, Emmen, Amsterdam, Zuidhorn and Groningen). Care providers are defined in this study as the day-care employees responsible for the wellbeing of the child during the time the children are present in the day-care center. Children were included if their parents approved their participation. Furthermore, both children and care providers were excluded if they had a fever or another illness influencing body temperature. Parents indicated at arrival if their child had a temperature or fever, but usually the child was not in the day-care center in case of being ill. The care providers mentioned themselves if they felt ill or they were not in the day-care center as well.

2.2. Measures

At each day-care center measurements took place one day in winter and one day in summer in the year 2018 and 2019. Both days, the same measurements were completed three times a day; in the morning (9.00–10.00 a.m.), midday (12.00–13.00 p.m.) and in the late afternoon (15.00–16.00 p.m.).

To assess the out- and indoor climate of the day-care centers the temperature, humidity and Wet Bulb Globe Temperature (WBGT) was measured (3 M™ QUESTemp°, St. Paul Minnesota, USA, accuracy temperature 0.5 °C, relative humidity 5%). T_{sk} of the ring finger, forearm, cheek and forehead of the children and care providers were measured with a Voltcraft IR-230 infrared thermometer (Conrad Electronic, Hirschau, Germany, emissivity 0.95). These locations were chosen as they are not covered by clothes (only the forearm on a few occasions) and for ease of access. The sensor was positioned 3 cm from the skin without direct skin contact. Three devices were used. Although the accuracy of the devices was specified at 2.5 °C in the range of −35 to 250 °C, a comparison using an iButton (DS1922L, Maxim Integrated Products Inc, Sunnyvale, CA, USA) in the expected temperature range of T_{sk} (between 17 °C and 37 °C) resulted in a deviation of 0.3 ± 0.5 °C (mean ± SD).

Whole body thermal sensation (TS) was assessed with a 9-point scale (from −4 = very cold to +4 = very hot) [22]. The care providers scored their own thermal sensation (TS_{cp}) and were instructed to report the TS they believed matched best with that of the child (TS_{child}). Physical activity of the children who were able to walk was determined with a pedometer (Yamax SW200, Tokyo, Japan, accuracy 10%). Pedometers are proven to be a reliable measure of physical activity, also in pre-school children [23,24]. The children wore the pedometer from the moment they arrived at the day-care center until they, or the researcher left. The clothing of the children and care providers were assessed and afterwards the thermal insulation of the clothing was calculated in clo (1 clo = 0.155 m^2 K W^{-1}) using ISO standard 9920 [25]. The weight and height of the children was measured with a weighing scale (Medisana, Germany, Neuss) and measuring tape.

The care providers knowledge of thermoregulation in children, temperature related illnesses and precautionary measures to reduce cold and heat exposure were assessed with an interview containing eight open ended questions specifically developed for this study (see Appendix A of the supplementary data for the questions translated from Dutch to English). The interviews with the care providers were analyzed by two independent researchers (authors MF and MZ) by quantifying each answer into a category. Next, scores were defined for the questions regarding the knowledge of the care providers what is insufficient and sufficient knowledge (see Appendix B of the supplementary data for the correct answers and the classification of the knowledge scores).

2.3. Statistical analysis

The data was analyzed using RStudio 1.1.463 and Stata 16.0. Mean T_{sk} was calculated per individual and measurement moment using an unweighted average of T_{sk} of the four locations and was assumed to represent the thermal state of the children and care providers. Analysis of winter and summer data were conducted separately and then combined, with the latter referred to as the 'total period'. To test for differences between the thermal state of the children and care providers at different indoor WBGT temperatures an ANCOVA was performed with T_{sk} of the four locations and mean T_{sk} as a dependent variable, individual (child or care provider) as independent variable and WBGT indoor as a covariate.

Multilevel mixed-effects linear regression analysis was used for part of the analysis as the data is hierarchically structured. Four different models where fitted with each different levels (considered levels were day-care center, group, child and/or care provider) and the residuals were distributed normally. The first model (A) was fitted with a random intercept for child (level 1) and day-care center (level 2) to test which parameters effect mean T_{sk} of the children the most. Parameters included in this model are WBGT in- and outdoor, clo value, number of steps, BMI, age and sex of the child. The second model (B) was fitted with a random intercept for care provider (level 1) and day-care center (level 2) to test which parameters predominately affected the care providers mean T_{sk}. Parameters included were WBGT in- and outdoor and clo value. The third and fourth model were fitted with a random intercept for care provider only, to determine the relation between TS_{cp} and mean T_{sk} of the care provider (model C) and between the TS_{child} and the mean T_{sk} of the child (model D).

3. Results

In total, 104 children (<four years old) and 58 care providers participated in the current study. Twenty-two children and 16 care providers participated both in winter and summer. Of the 104 children, 49 were female and 55 were male. The care providers were all female, apart from one male. Table 1 shows the characteristics of the day-care centers, the children and care providers, separated for winter and summer measurements.

Table 2 shows the mean daily ambient temperature, relative humidity and WBGT measured in the morning, midday and afternoon both in- and outside the day-care centers in winter and summer, as well as the median T_{sk} and clo value of the children and care providers. The median number of steps taken per hour by the children is reported as well. As expected ambient temperature and WBGT for both in- and outside of the day-care center were higher in summer than in winter, but no extreme temperatures were observed. Fig. 1 shows the relation between WBGT indoor and T_{sk} of the ring finger, forearm, cheek, forehead and the mean of the children and care providers and the results of the ANCOVA are shown in Table 3. When considering the total period, significant differences ($P < 0.05$) in T_{sk} between children and care providers were found for all four body locations, but not for the mean T_{sk}. Ring finger and forehead of the children was consistently higher, while the temperature of the forearm and cheek of the children was consistently lower than the care providers. In summer and winter separately, the differences in the T_{sk} of the ring finger and forehead were not significantly different between children and care providers, with $p = 0.296$ and $p = 0.134$ for the ring finger and $p = 0.124$ and $p = 0.075$ for the forehead in summer and winter respectively.

Table 4 shows the results of the multilevel mixed-effects linear regression analysis for model A, B, C and D for the total period and for winter and summer separately. Mean T_{sk} is mostly dependent on WBGT indoor in both the children ($p < 0.001$) and the care providers ($p < 0.01$). However, in the winter mean T_{sk} of the care providers is not significantly correlated with WBGT indoor ($p = 0.20$), but significantly related to WBGT outdoor ($P < 0.05$). Furthermore, mean T_{sk} of the children in the total period is also significantly correlated with physical activity, age and sex ($p < 0.05$) and in the summer and the winter separately with the sex of the child ($p < 0.05$). No significant correlations are found between the mean T_{sk} of the children and the clothing and BMI and between the mean T_{sk} of the care providers and clothing.

For the total period a significant relationship was found between TS_{cp} and the mean T_{sk} of the care provider ($p < 0.01$), as well as for TS_{child} and the mean T_{sk} of the children ($p < 0.05$). However, when considering summer and winter separately, only a significant relationship was found between TS_{cp} and the mean T_{sk} of the care provider ($p < 0.01$), and no significant relationship was found between the TS_{child} and the mean T_{sk} of the children. Fig. 2 shows TS_{cp} and TS_{child} compared to the mean T_{sk} for the total period and winter and summer separately. The boxplot in winter and summer show a larger variation of mean T_{sk} of the children for most of the TS_{child} compared to the mean T_{sk} and TS_{cp}, which may explain the non-significant relationship.

3.1. Interviews

Fifty-three of the 58 care providers were able to complete the interviews. Table 5 shows the amount of the care providers who gave a certain answer at each question subdivided into precautionary measures and knowledge. During days of low ambient temperatures most care providers (69.8%) answered they would put more clothes on the children as precautionary measure, followed by turning up the indoor heating (50.9%). During days of high ambient temperatures, most care providers (52.8%) answered they would give more (cold) drinks to the children or let them play with water outdoors (43.4%).

The most common answer on the first knowledge question; how the care providers notice a child is cold, was with feeling the child has cold skin (hands/feet) (50.9%), while in the heat the most answered symptom was by the red face of the child (67.9%). Furthermore, most care providers answered the question regarding the consequences of exposing a child to the cold or heat for too long with hypothermia (69.8%) and hyperthermia (71.7%) respectively. The most reported symptom of heat illness was a headache (24.5%), followed by tiredness (22.6%) and nausea or vomiting (22.6%). Twelve care providers (22.6%) could not name any symptom. The last question of the interview was if there is a difference between children and adults in how well they cope with extreme temperatures, which most care providers (71.7%) answered with that adults cope better with extreme temperatures.

Table 6 shows the knowledge rating of all the care providers and subdivided into care providers with some experience (SE; ≤ 5 years) and much experience (ME; >5 years) with working in day-care centers. From two care providers the amount of years' experience was unknown and therefore they were excluded from this part of the analysis. The care providers seem to be able to describe the signs of a child being cold or hot quite well based on this questionnaire with respectively 92.1% and 88.2% rated with sufficient knowledge, 3.9% and 9.8% with some knowledge and no one with no knowledge. Further, the care providers could name well what the consequences are of the exposure of a child to the cold or heat for too long with respectively 70.6% and 72.5% rated with sufficient knowledge and 23.5% and 19.6% with some knowledge. Only two (3.9%) care providers could not name the consequences of exposure of a child to the cold for too long. The care providers had more difficulties naming the symptoms of heat illness in children as only

Table 1
Characteristics of the day-care centers, children and care providers during winter and summer.

Season	Day-care	Location	Children				Weight (kg) (median (IQR))	Care providers		
			N	Age (Month) (median (IQR))	Gender (M/F)	Height (cm) (median (IQR))		N	Gender (M/F)	Experience (Years) (median (IQR))
Winter	1	Arnhem	10	28 (23–32)	5/5	88 (88–88)	14 (12–14)	8	0/8	12 (4–14)
	2	Assen	16	25 (19–38)	12/4	88 (81–96)	13 (12–15)	14	0/14	3 (2–5)
	3	Emmen	6	20 (16–34)	1/5	82 (80–92)	12 (11–16)	4	0/4	2 (1–7)
	4	Amsterdam	13	23 (17–33)	8/5	87 (76–97)	14 (10–17)	6	0/6	13 (8–25)
	5	Zuidhorn	14	27 (18–33)	7/7	91 (89–100)	15 (14–16)	5	0/5	2 (1–14)
	6	Groningen	12	24 (20–33)	7/5	88 (81–96)	13 (11–16)	9	1/8	16 (11–18)
	All	–	71	26 (18–34)	40/31	88 (81–97)	14 (12–16)	46	1/45	5 (2–14)
Summer	1	Arnhem	8	33 (30–35)	4/4	93 (91–98)	14 (13–16)	4	0/4	3 (2–8)
	2	Assen	16	23 (21–34)	11/5	87 (85–95)	13 (11–14)	6	0/6	3 (3–5)
	3	Emmen	8	30 (20–40)	4/4	91 (87–98)	13 (11–14)	3	0/3	20 (10–24)
	4	Amsterdam	10	21 (12–29)	4/6	79 (72–89)	11 (10–13)	6	0/6	13 (8–25)
	5	Zuidhorn	5	18 (7–27)	3/2	86 (70–96)	12 (8–13)	2	0/2	7 (4–9)
	6	Groningen	8	24 (20–35)	2/6	86 (85–95)	13 (13–14)	7	1/6	17 (12–18)
	All	–	55	24 (18–34)	28/27	88 (83–96)	13 (11–14)	28	1/27	10 (3–18)

IQR=Interquartile range.

Table 2

Median and interquartile range (IQR) of indoor and outdoor temperature (T) (°C), humidity (RH) (%), Wet Bulb Globe Temperature (WBGT) (°C), and mean skin temperature (T_{sk}) (°C) and clo (median (IQR)) of the children and care providers in winter and summer averaged over all included day-care centers for time of day (morning, midday and afternoon). The median number of steps per hour taken in winter and summer by the children is reported as well.

Season	Time of day	Outdoor			Indoor			Children			Care providers	
		T (°C) (median (IQR))	RH (%) (median (IQR))	WBGT (°C) (median (IQR))	T (°C) (median (IQR))	RH (%) (median (IQR))	WBGT (°C) (median (IQR))	T_{sk} (°C) (median (IQR))	Clo (median (IQR))	Steps (median (IQR))	T_{sk} (°C) (median (IQR))	Clo (median (IQR))
Winter	Morning	6.0 (5.6–7.5)	62 (44–67)	5.8 (4.7–7.0)	20.2 (19.1–21.1)	43 (37–51)	16.6 (15.8–17.4)	29.5 (27.3–31.1)	0.7 (0.6–0.8)	756 (554–921)	29.6 (27.6–30.6)	0.8 (0.6–0.8)
	Midday	7.2 (6.3–10.6)	50 (48–60)	6.7 (5.5–9.0)	20.6 (19.5–21.4)	44 (34–50)	17.1 (16.1–18.1)	30.1 (28.1–31.5)	0.7 (0.6–0.8)	–	30.4 (28.9–31.5)	0.8 (0.6–0.8)
	Afternoon	9.4 (7.6–11.7)	48 (41–65)	6.7 (0.3–9.1)	20.3 (19.6–22.0)	41 (32–49)	16.9 (16.2–17.9)	29.7 (28.3–31.7)	0.7 (0.6–0.8)	–	30.4 (29.6–31.7)	0.8 (0.6–0.8)
Summer	Morning	20.3 (18.4–20.6)	66 (51–69)	18.6 (17.7–20.2)	22.2 (21.3–23.4)	61 (57–67)	19.7 (19.4–20.9)	30.9 (29.8–31.9)	0.5 (0.4–0.8)	742 (592–933)	30.9 (30.2–31.6)	0.5 (0.5–0.6)
	Midday	21.5 (20.4–22.8)	49 (44–56)	20.0 (19.2–20.6)	23.7 (22.8–24.3)	56 (53–60)	20.6 (20.0–21.2)	31.5 (30.8–32.2)	0.5 (0.3–0.5)	–	31.6 (30.6–32.6)	0.5 (0.4–0.5)
	Afternoon	22.0 (20.8–25.0)	52 (41–58)	19.9 (19.0–23.1)	23.9 (22.9–24.9)	57 (48–58)	21.0 (20.5–21.2)	32.1 (31.0–33.0)	0.5 (0.3–0.5)	–	32.1 (31.8–32.6)	0.5 (0.4–0.5)

13.7% were rated with sufficient knowledge, 62.7% with some knowledge and 23.5% with insufficient knowledge. Only 29.4% of the care providers did not know that children have more difficulties coping with extreme temperatures than adults. Care providers with more years of work experience in day-care centers had a higher percentage of sufficient knowledge and lower percentage of insufficient knowledge than care providers with less experience for five out of the six questions. Only in question 6; is there a difference between children and adults in how well they cope with extreme temperatures?), care providers with less experience had a higher percentage of sufficient knowledge than care providers with more experience with 59.3% vs 83.3% respectively.

4. Discussion

Young children are mostly dependent upon adults with regard to behavioural thermoregulation. As their thermophysiological responses may be insufficient compared to adults it is important that adults can accurately estimate the thermal state of their dependent child and act accordingly. To our knowledge this is the first study to assess care providers estimation of children's thermal state in day-care centers. As care providers of children, who are unable to clearly express their thermal state due to age-related inability, limited vocabulary and inexperience, it is important to be able to recognize when children are at risk of temperature related illnesses. Therefore, this study also aimed to assess the knowledge of the care providers regarding the thermoregulation of children and temperature related illnesses.

4.1. Thermal state

The current study showed significant differences in T_{sk} of the ring finger, forearm, cheek and forehead between the children and care providers, with the T_{sk} of the forearm and the cheek of the children consistently lower and of the ring finger and forehead consistently higher than the care providers. These differences in local T_{sk} between the children and care providers are in line with previous research where differences in local T_{sk} from early childhood into adulthood were reported [26]. Activity level, clothing and BMI were reported to possibly account for these differences [26]. In the current study however, next to indoor WBGT, which has the largest effect on T_{sk} of both the children and care providers, only sex, age and activity level seemed to influence T_{sk} of the children. No influence of clothing and BMI was found. A potential explanation for this may be that the locations where T_{sk} was measured in this study were mostly uncovered by clothing. Furthermore, BMI tended to influence T_{sk} locations where an increase of BMI was more apparent, like the upper chest and abdomen [26], which were not included in this study.

The local differences in T_{sk} in the current study between the children and care providers might also be due to physiological differences. Another study reported higher local T_{sk} in children of 9 years old compared to children of 13 years old while exercising at a similar relative intensity, which may be due to a lower sweat rate in the younger children [27]. However, as activity level and clothing in the current study were not matched, we cannot state that the difference in local T_{sk} was mainly due to physiological differences. Therefore, future studies should focus on comparing regional distribution of local T_{sk} between young children and adults while matching for activity level and clothing to get a better understanding if the differences have a physiological or behavioural origin.

We found no differences in mean T_{sk} between the children and care providers and therefore the thermal state is considered to be similar. This is contrary to what was expected, since it was hypothesized that the thermal state of children would be different than the thermal state of adults. However, the thermal conditions in the current study were less extreme than expected beforehand with an indoor WBGT between 12 °C and 23 °C. Previous studies showed that children are predominantly more at risk at extreme low or high temperatures and that their

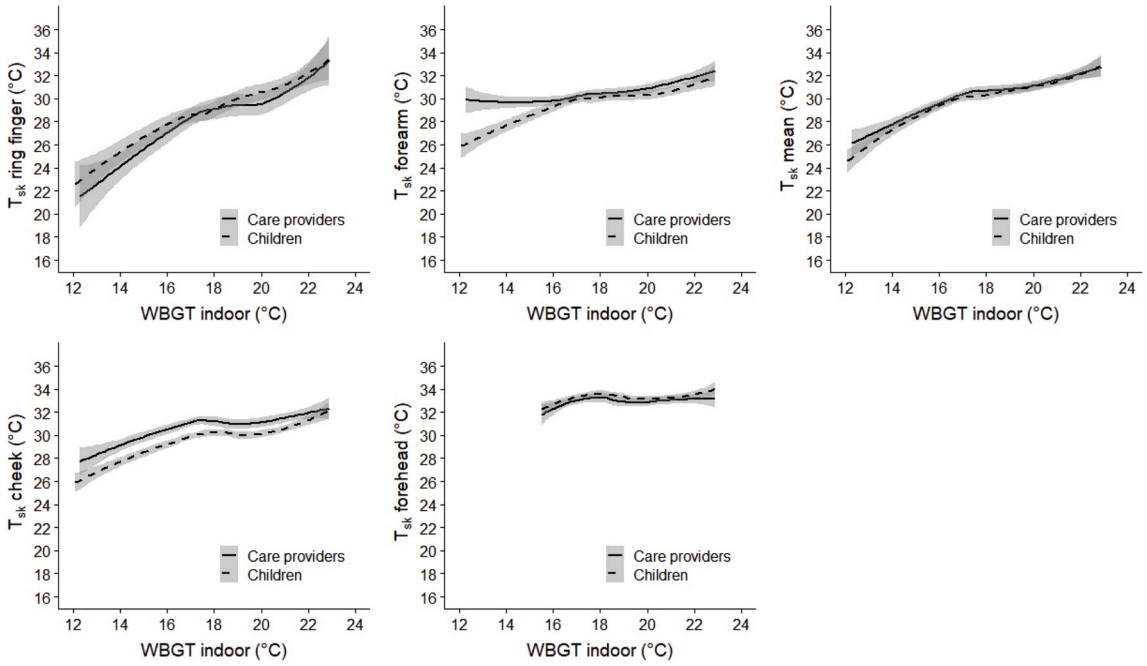

Fig. 1. Skin temperature (T_{sk}) (°C) of the ring finger, forearm, cheek, forehead and the mean (mean ± 95% confidence interval) of the children (dashed lines) and care providers (solid lines) related to WBGT indoor (°C). In two day-care centers T_{sk} of the forehead was not measured during the winter, resulting in missing data for WBGT indoor between 12 °C and 16 °C.

Table 3
Output from the ANCOVA to test for the difference in skin temperature (T_{sk}) (°C) of the ring finger, forearm, cheek, forehead and the mean T_{sk} between children and care providers with WBGT indoor as covariate for the total period, winter and summer. P-values marked in bold are significantly lower than 0.05.

T_{sk}	Response variable	Total period					Winter					Summer				
		Sum of squares	df	Mean square	F	P-value	Sum of squares	df	Mean square	F	P-value	Sum of squares	Df	Mean square	F	P-value
Ring finger	CC[a]	55.6	1	55.6	4.2	**0.041**	18.3	1	18.3	1.1	0.296	19.0	1	19.0	2.3	0.134
	WBGT	2367.5	1	2367.5	178.4	**0.000**	1040.9	1	1040.9	62.3	**0.000**	199.0	1	199.0	23.8	**0.000**
Forearm	CC[a]	46.4	1	46.4	14.2	**0.000**	36.1	1	36.1	8.4	**0.004**	17.8	1	17.8	10.0	**0.002**
	WBGT	407.6	1	407.6	124.6	**0.000**	211.1	1	211.1	49.3	**0.000**	63.2	1	63.2	35.6	**0.000**
Cheek	CC[a]	131.0	1	131.0	52.8	**0.000**	93.6	1	93.6	35.3	**0.000**	47.0	1	47.0	28.5	**0.000**
	WBGT	455.1	1	455.1	183.4	**0.000**	385.4	1	385.4	145.6	**0.000**	115.4	1	115.4	70.0	**0.000**
Forehead	CC[a]	7.8	1	7.8	5.5	**0.019**	3.0	1	3.0	2.4	0.124	4.8	1	4.8	3.2	0.075
	WBGT	10.7	1	10.7	7.5	**0.006**	19.5	1	19.5	15.6	**0.000**	5.4	1	5.4	3.6	0.060
Mean	CC[a]	4.6	1	4.6	1.4	0.233	8.3	1	8.3	2.0	0.158	1.3	1	1.3	0.8	0.362
	WBGT	987.4	1	987.4	308.5	**0.000**	576.1	1	576.1	138.1	**0.000**	77.1	1	77.1	50.4	**0.000**

[a] Children/care providers.

thermoregulation is similar to adults during moderate thermal conditions [6]. This may explain why in the current study no differences in thermal state between the children and care providers were found. Future studies should include a wider range of ambient temperatures.

4.2. Estimating thermal state

Whilst thermal state was found to be similar between the children and care providers, the results of this study show that the care providers did not correctly estimate the thermal state of the children in line with the second hypothesis. A significant relation was found between mean T_{sk} and TS_{cp} for the total period, as well as for winter and summer separately. However, the relation between T_{sk} and TS_{child} for the total period was significant, but for winter and summer separately insignificant. As care providers estimate the thermal state of a child within a small time frame and act accordingly, it seems more important that they are able to correctly estimate the thermal state of the child within a season than over the total period. For instance, a previous study showed that a mean T_{sk} higher than 32 °C, measured at the same locations as this study, typically matches with a neutral to hot thermal sensation [21]. In the current study, on multiple occasions care providers reported the thermal sensation of children with a mean T_{sk} lower than 25 °C as 'neutral' or 'slightly warm' (see Fig. 2), which possibly results in an incorrect behavioural action of the care provider to adjust the thermal environment in such a way to make it more comfortable.

Furthermore, a study comparing the thermal comfort of 4 and 5 year old children with adults reported the children felt overall 'slightly warmer' than the adults, most likely due to the difference in metabolic rate [28]. Therefore, dressing the children with similar clothing as yourself as care provider or parent, or adjusting the room temperature for your own thermal comfort is most likely not optimal for the child.

4.3. Interviews

Care providers were asked what kind of precautionary measures were taken in the day-care centers to reduce cold and heat exposure to get an overview of the policies employed. Most answers relating to precautionary measures during days of high ambient temperatures were

Table 4
Multilevel mixed-effects linear regression analysis for the relation between the mean skin temperature of the child ($T_{sk\ child}$) (°C) (model A) and care provider ($T_{sk\ cp}$) (°C) (model B) with selected independent variables, the relation between thermal sensation ranked by the care provider for themselves (TS_{cp}) with $T_{sk\ cp}$ (model C) and estimated for the children (TS_{child}) (model D) with $T_{sk\ child}$. All models are calculated for the total period and winter and summer separately.

Model	Dependent variable	Independent variable	Total period		Winter	SE[a]	Summer	SE[a]
			Coefficient	SE[a]	Coefficient		Coefficient	
A	Mean $T_{sk\ child}$	$WBGT_i$[b]	0.68***	0.14	0.72**	0.22	0.60**	0.16
		$WBGT_o$[c]	−0.02	0.04	−0.10	0.11	0.08	0.05
		Clothing	0.86	1.13	−1.08	1.58	2.24	1.10
		Steps	−0.00*	0.00	−0.00	0.00	−0.00	0.00
		BMI	0.01	0.11	0.03	0.15	−0.17	0.09
		Age	0.05*	0.03	−0.03	0.44	0.01	0.02
		Sex	0.73*	0.34	0.98*	3.92	0.65*	0.29
		Intercept	16.24***	2.81	16.87***	4.14	19.23***	3.29
B	Mean $T_{sk\ cp}$	$WBGT_i$[b]	0.44**	0.13	0.27	0.21	0.53***	0.13
		$WBGT_o$[c]	0.02	0.04	0.22*	0.09	0.06	0.05
		Clothing	0.88	0.86	−0.30	1.50	1.01	1.24
		Intercept	21.83***	2.15	24.24	3.43	18.94***	2.65
C	TS_{cp}	Mean $T_{sk\ cp}$	0.20***	0.03	0.16***	0.24	0.25**	0.05
		Intercept	−5.67***	0.99	−4.5***	0.51	−7.39**	1.45
D	TS_{child}	Mean $T_{sk\ child}$	0.03*	0.01	0.01	0.01	0.04	0.03
		Intercept	−0.47	0.30	−0.11	0.33	−0.86	0.82

*p < 0.05, **p < 0.01, *** <0.001.
[a] Standard error.
[b] WBGT indoor.
[c] WBGT outdoor.

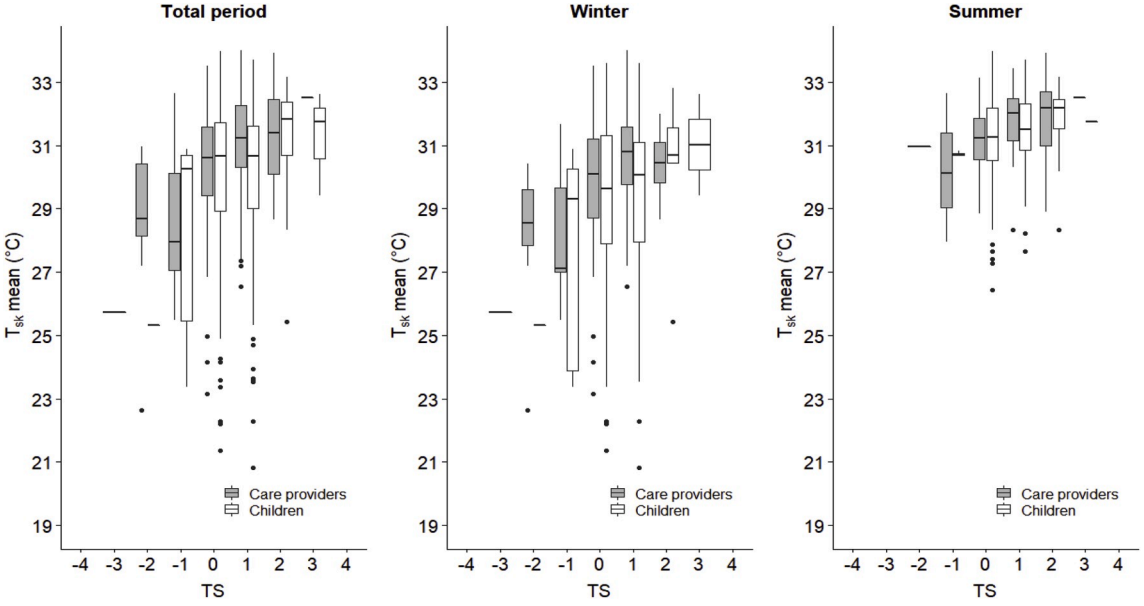

Fig. 2. Boxplots of the thermal sensation score (TS) of care provider and the mean skin temperature (T_{sk}) (°C) and TS of the children estimated by the care provider compared to the mean $T_{sk\ (°C)}$ of the children. TS was ranked between −4 (very cold) and 4 (very hot). The box represents the interquartile range (IQR), the whiskers ±1.5 * IQR, the horizontal line within the box is the median and the black dots are outliers. In a few cases only a horizontal line is shown which means only one care provider mentioned that specific TS score.

in line with the advice provided by The Netherlands National Institute for Public Health and the Environment (Dutch: RIVM) [29]. Surprisingly, air conditioning or fans are not used much with only 13.2% of the care providers mentioning it as a precautionary measure during hot days. Not many guidelines are provided by the RIVM regarding days with low ambient temperatures. The focus is mainly on maintaining the temperature indoors at 20 °C and in the bedrooms of the children between 15 °C and 18 °C. With 50.9% of the care providers answering they would turn up the indoor heating during cold days this was also one of their main focus areas.

Six different questions were asked during the interview to get an overview of care providers knowledge regarding thermoregulation and temperature related illnesses in children. The care providers reported many signs of a child being cold or hot with 92.1% and 88.2% (respectively) rated with sufficient knowledge on these questions. This finding is surprising since the results of this study also showed large variations in the care providers estimation of the thermal state of the children. A reason for this might be that some of the signs listed by the care providers for being cold (e.g. blue lips, chatter teeth, shivering) or hot (e.g. sweating, behaving sleepy or drowsy, thirsty) are only present when a child is very cold or hot, whilst in the current study that probably was not the case since the ambient conditions were fairly moderate. Furthermore, the care providers could name the consequences of exposing a child for too long to the cold and the heat quite well with respectively 94.1% and 92.1% sufficient or some knowledge. However, some of the care providers were not always able to name all the

Table 5
Number of care providers (%) providing a certain answer for each question asked during the interview. On Q1-Q7 care providers could provide multiple answers.

Question	Answer	Amount care providers providing answer
Precautionary measures		
Q1 What precautionary measures are taken in the day-care center during cold days?	Add clothes	37 (69.8%)
	Turn up the indoor heating	27 (50.9%)
	Reduce playing time outdoors	15 (28.3%)
	Close windows/doors	8 (15.1%)
	Hot water bottle in children's bed	3 (5.7%)
	Drink warm fluids	1 (1.9%)
	Do not know	0 (0.0%)
	No answer/ misunderstood	0 (0.0%)
Q2 What precautionary measures are taken in the day-care center during hot days?	Provide more (cold) drinks	28 (52.8%)
	Play with water outdoors	23 (43.4%)
	Take clothes off	22 (41.5%)
	Open/close windows (depended on temperature difference)	19 (35.8%)
	Adjust time playing outside to cooler moments	18 (34.0%)
	Create shadow places outdoors	16 (30.2%)
	Window blinds	16 (30.2%)
	Air-conditioning/ ventilator	7 (13.2%)
	Do not know	0 (0.0%)
	No answer/ misunderstood	0 (0.0%)
Knowledge		
Q3 How do you notice a child is cold?	Cold skin (hand/feet)	27 (50.9%)
	Verbally express they are cold	20 (37.7%)
	Blue lips	19 (35.8%)
	Shivering	16 (30.2%)
	Crying	11 (20.7%)
	Reduced movement	7 (13.2%)
	Pale face	3 (5.7%)
	Want to sit on lap/cuddle	2 (3.8%)
	Chatter teeth	2 (3.8%)
	Wants to go indoors	2 (3.8%)
	Do not know	0 (0.0%)
	No answer/ misunderstood	0 (0.0%)
Q4 How do you notice a child is hot?	Red face	36 (67.9%)
	Sweating	31 (58.5%)
	Sleepy/drowsy	13 (24.5%)
	Warm skin (hands/feet/ forehead)	11 (20.7%)
	Crying	9 (17.0%)
	Take off clothes	9 (17.0%)
	Verbally express they are warm	8 (15.1%)
	Thirsty	5 (9.4%)
	Increased breathing	1 (1.9%)
	Do not know	0 (0.0%)
	No answer/ misunderstood	0 (0.0%)
Q5 What can be the consequences when a child is exposed to the cold for too long?	Hypothermia	37 (69.8%)
	Child gets a cold/sick	9 (17.0%)
	Symptom of hypothermia (e.g. shivering/adjusted breathing)	7 (13.2%)
	Do not know	2 (3.8%)
	No answer/ misunderstood	1 (1.9%)
		38 (71.7%)
Q6 What can be the consequences when a child is exposed to the heat for too long?	Hyperthermia/heat stroke	
	Symptom of hyperthermia (e.g. dehydration/drowsiness)	12 (22.6%)
	Do not know	0 (0.0%)
	No answer/ misunderstood	3 (5.7%)
Q7 What are the symptoms of heat illness in a child?	Headache	13 (24.5%)
	Tiredness	12 (22.6%)
	Nausea/vomiting	12 (22.6%)
	Fainting	9 (17.0%)
	(absence of) sweating	8 (15.1%)
	Glowing/fever	7 (13.2%)
	Acting confused	7 (13.2%)
	Pale/red face	6 (11.3%)
	Dizziness	2 (3.8%)
	Do not know	12 (22.6%)
	No answer/ misunderstood	0 (0.0%)
Q8 Is there a difference between children and adults in how well they cope with extreme temperatures?	Yes, children are more vulnerable	38 (71.7%)
	Yes, adults are more vulnerable	6 (11.3%)
	No	6 (11.3%)
	Do not know	3 (5.7%)
	No answer/ misunderstood	0 (0.0%)

symptoms of heat illness with only 13.7% rated with sufficient knowledge on this question and 23.5% who could not name any symptoms. Also, 29.4% of the care providers believed there was no difference in how well children and adults cope with extreme temperatures or believed that children actually cope better. The outcome of the last two questions is quite worrying since the risk for children getting a heat related illness increases with more and more days of extreme ambient temperatures due to climate change [11].

A clear difference in the knowledge of the care providers existed, with many years of experience (>5 years) working in day-care centers compared to care providers with less experience (≤5 years). On every question, except the question about the difference between children and adults in coping with extreme temperatures, the care providers with more experience were rated with more knowledge. This may be due to the lack of attention for the effect of temperature on children in the education of care providers as mentioned several times during the interviews.

4.4. Limitations

In this study only T_{sk} was used to represent the thermal state of the children and care providers and core temperature was not measured. It has previously been shown that thermal sensation is strongly influenced by and can be predicted well with T_{sk} [20,21]. This has clearly been demonstrated in healthy adults but it has not been systemically shown in children as thermophysiological data of children is limited. As such we have assumed that the thermal state of each child is also dependent upon their mean T_{sk} as demonstrated in adults. Furthermore, the accuracy of the thermometer used to measure T_{sk} in this study is limited with 2.5 °C according to the specifications of the device. However, a comparison with an iButton showed a deviation of 0.3 ± 0.5 °C (mean ± SD) in the range T_{sk} observed in this study. Nevertheless, additional research in this area may consider more sensitive devices to provide greater accuracy. Furthermore, as the thermal conditions were not quite extreme, the children and care providers were most likely in the thermoneutral zone and their core temperature did not vary that much [30]. Therefore, T_{sk}

Table 6
Rating of the knowledge of the care providers based on six interview questions. Sufficient knowledge is defined as the care provider naming ≥2 symptoms in Q3 and Q4, or only cold skin, shivering, blue lips or chatter teeth in Q3 and only warm/pale/clammy skin in Q4, naming hypothermia in Q5 and hyperthermia in Q6, naming ≥3 symptoms in Q7, answered that adults cope better with extreme temperatures in Q8. Some knowledge is defined as the care provider naming 1 symptom in Q3 and Q4, naming symptoms of hypothermia in Q5 and of hyperthermia in Q6, naming 1 or 2 symptoms in Q7, some knowledge was not possible in Q8 as it is a right or wrong question. Insufficient knowledge is defined as the care provider naming 0 symptoms in Q3 and Q4, answering I do not know in Q5 and Q6, naming 0 symptoms in Q7 and answering that children and adults cope equally well or children cope better with extreme temperatures in Q8. The results are shown for all care providers and subdivided into care providers with some experience (SE) (≤5 years) and much experience (ME) (>5 years).

Knowledge questions	Sufficient knowledge (N)			Some knowledge (N)			Insufficient knowledge (N)			N.A.[a]		
	All	SE	ME	All	SE	ME	All	SE	ME	All	SE	ME
Q3 How do you notice a child is cold?	47	21 (87.5%)	26 (96.3%)	2	1 (4.2%)	1 (3.7%)	0	0 (0.0%)	0 (0.0%)	2	2 (8.3%)	0 (0.0%)
Q4 How do you notice a child is hot?	45	21 (87.5%)	24 (88.9%)	5	3 (12.5%)	2 (7.4%)	0	0 (0.0%)	0 (0.0%)	1	0 (0.0%)	1 (3.7%)
Q5 What can be the consequences when a child is exposed to the cold for too long?	36	15 (62.5%)	21 (77.8%)	12	7 (29.2%)	5 (18.5%)	2	2 (8.3%)	0 (0.0%)	1	0 (0.0%)	1 (3.7%)
Q6 What can be the consequences when a child is exposed to the heat for too long?	37	15 (62.5%)	22 (81.5%)	10	7 (29.2%)	3 (11.1%)	0	0 (0.0%)	0 (0.0%)	4	2 (7.4%)	2 (7.4%)
Q7 What are the symptoms of heat illness in a child?	7	1 (4.2%)	6 (22.2%)	32	13 (54.2%)	19 (70.4%)	12	10 (41.7%)	2 (7.4%)	0	0 (0.0%)	0 (0.0%)
Q8: Is there a difference between children and adults in how well they cope with extreme temperatures?	36	20 (83.3%)	16 (59.3%)	–	–	–	15	4 (16.7%)	11 (40.7%)	–	–	–

[a] No answer or misunderstood question.

was in this study most likely the main driver of thermal sensation. However, more research is warranted to investigate this, especially if more extreme thermal conditions are used. The analysis and rating of the answers of the care providers on the interviews was completed to the best of our knowledge, and decisions were made cautiously and after a thorough discussion. However, as there is no standardized way available to analyse such questionnaires, it should be considered that the choices made potentially influenced the results. Furthermore, the current study was executed in day-care centers, whilst children spend of course most of their time at home with their parents. It may be the case that parents know less about the effect of the heat on children than care providers in a day-care center since in general they had no education regarding this topic at all. Future studies should focus on parents and the situation at home.

5. Conclusion

Thermal state of care providers was related to their thermal sensation, but the thermal state of children was unrelated to the assessed thermal sensation by the care providers. As thermoregulatory mechanisms are not fully developed at a young age and care providers had difficulties naming the correct symptoms of heat illness, the risk of temperature related illnesses is elevated. It is recommended to train care providers in thermal assessment, in particular novice care providers that appear to have less awareness on this topic.

Funding

This work was supported by the project ClimApp, which is part of ERA4CS, an ERA-NET initiated by JPI Climate, and funded by FORMAS (SE), IFD (DK), NWO (NL) with co-funding by the European Union (Grant 690462).

Author's contributions

MF and HD conceived and designed the study. MF performed the experiments. MF, NG and MZ analyzed the data. MF drafted the manuscript and NG, BK, MZ and HD critically reviewed the manuscript. All authors gave approval for submission of the manuscript.

Declaration of competing interest

None.

Appendix. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.buildenv.2020.106915.

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