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REVIEW OF COMFORT STANDARDS IN WEIGHT AND GROUP FITNESS ROOMS AND COMPARISON WITH MONITORED AND PERCEIVED DATA

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Thermal Comfort and, more generally Indoor Environmental Quality (IEQ) are key aspects of designing new buildings. For what regards sports centres, different regulations are depending not only on the type of activity practiced but also on the country and region. The present article aims to resume the information stated in different norms across Spain and abroad about design parameters (dimensions and characteristics) for weight rooms and group fitness rooms. A broader pool of laws, recommendations and guides are analysed and compared for what concerns the IEQ parameters (with a special focus on air temperature, relative humidity and CO2 concentrations). This review is contrasted with data gathered through monitoring performed in different weight rooms and group fitness rooms in a sports centre in Barcelona. Additionally, results from a thermal comfort survey shared among the users of the sports facility are compared to the indoor environmental collected data. Last, all air temperature, relative humidity and CO2 concentrations measurements were associated with measured occupancy numbers respectively. The study allows for identifying the maximum number of occupants per room for keeping adequate thermal comfort levels and air quality.

Keywords: indoor environmental quality; thermal comfort; sports buildings; post occupancy-evaluation; monitoring campaign

REVISIÓN DE NORMATIVAS DE CONFORT EN SALAS FITNESS Y DE ACTIVIDADES DIRIGIDAS Y COMPARACIÓN CON LOS DATOS MONITORIZADOS Y PERCIBIDOS

El confort térmico y, generalmente la calidad del ambiente interior (IEQ) son aspectos clave a la hora de diseñar nuevos edificios. En centros deportivos, existen diferentes reglamentaciones dependiendo del tipo de actividad que se practica, del país o incluso de la región. El presente artículo, tiene como objetivo resumir la información de diferentes normativas a lo largo de España y el extranjero sobre los parámetros de diseño para salas de actividades dirigidas y salas de fitness. Un abanico más amplio de leyes, recomendaciones y guías son comparadas en cuanto a los parámetros que rigen el IEQ (prioritariamente la temperatura del aire, la humedad relativa y la concentración de CO2). Esta revisión es contrastada con datos recogidos gracias a una monitorización realizada en diferentes salas en un centro deportivo de Barcelona. Además, se comparan los resultados de confort térmico de una encuesta realizada entre los usuarios del centro deportivo con los datos ambientales recogidos. Finalmente, las medidas de temperatura del aire, humedad relativa y concentración de CO2 son asociadas con los valores de ocupación medidos respectivamente. El estudio permite identificar el número máximo de ocupantes por sala para mantener un nivel de confort térmico i de calidad del aire adecuado.

Palabras clave: calidad del ambiente interior; confort térmico; instalaciones deportivas; avaluación post ocupacional; monitorización

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1. Introduction

Thermal comfort has become one of the key factors in buildings. Countries have developed norms about thermal comfort parameters depending on the final use. It works for offices, hospitals and many workplaces, but still does not cover all the different kinds of buildings. Sports centres are often clustered with other facilities and not recognized as specific facilities with singular needs. In Spain, the current thermal comfort and air quality regulations might be confusing depending on the reference used. Specifically, regulations are even scarcer and widespread between rooms within sports centres.

In 2020, approximately 6 out of 10 people over the age of 15 practised some kind of sport in Spain, either periodically or occasionally (División de Estadística y Estudios, Técnica, and Deporte 2022). From that 60%, a large quantity is practised guided activities such as halterophyllia, cardio, corporal expression, spinning, which are activities usually performed inside rooms in sports centres. Therefore, it becomes of great importance to increase knowledge about comfort ranges for the practice of sports within sports halls depending on the type of activity performed.

1.1 Types of Sports Rooms

How comfort levels are achieved in sports rooms can vary greatly depending on the room typology and the type of activity performed within. The study reviews room typologies from several sports equipment censuses and other projects in Spain. The most relevant typologies come from the Catalan Sports Equipment Census (CEEC), the National Sports Equipment Census (CNID) and the Euskadi Sports Equipment Census (CEIDE) shows the different typologies of sports rooms found among the different censuses reviewed. These equipment censuses specify that rooms are closed spaces, without courts and where different activities can be performed. Moreover, they differ from sports halls in size as rooms are smaller and usually have a lower ceiling height. Typically, rooms are distinguished among them depending on their size and the type of activity provided that the activity performed is very specific or requires special equipment.

1.2 Comfort in Sports Rooms

Many of the references reviewed propose similar ranges to define the comfort levels in the previously mentioned room typologies. However, not all of them take into account the different categories of indoor environmental comfort: visual, thermal, acoustic and air quality (Ortiz, 2016). This section compares the regulations of different countries and regions that are summarized in Table 1. In Spain, the current regulation is “Reglamento de Instalaciones Térmicas de los Edificios” (RITE) (Asociación Técnica Española de Climatización y Refrigeración 2012). It indicates the ranges of operative temperature and relative humidity that should be maintained during the winter and summer season in buildings with sedentary activities (Summer: 23-25, Winter: 21-23). However, RITE mentions which might be the optimal operative temperature in different metabolic rate scenarios, but does not specify a range for sports centres.

Table 1 Types of different sports rooms found according to the Spanish equipment census.

Type of sports spaces	Criteria	Sources where it can be found
Sports room 1	Between 100 and 200 m^2	CEEC, CEIDE
Sports room 2	Between 200 and 300 m^2	CEEC, CEIDE

Sports room 3	Minimum 300 m^2	CEEC, CEIDE
Combat sports room	All combat rooms	CEEC, CNID, CEIDE
Fencing room	All fencing rooms	CEEC, CNID, CEIDE
Room with equipment	Rooms equipped with weight equipment	CEEC, CNID, CEIDE
Specialized room	Other rooms with specialized equipment	CEEC, CNID, CEIDE
Other rooms	Other rooms not included in the previous type, minimum of 50 m^2	CEEC, CNID, CEIDE
Other rooms, small	Other rooms not included in the previous type, less than 50 m^2	CEEC, CEIDE
Multipurpose rooms	Over 100 m^2	CNID
Archery rooms	All archery rooms	CEIDE
Shooting sport rooms	All shooting sports rooms	CEIDE

1.3 Post-occupancy Evaluations

The process of POE involves a systematic and thorough evaluation of buildings that have already been constructed and occupied for a certain period of time. This evaluation is conducted to assess the energy usage of the building and the occupants' perceptions of it. Post-occupancy evaluations (POE) are a useful tool to know the most suitable comfort ranges for a specific space. A monitoring performed by X.Huanga et. Al. (2022) surveyed the users of five sports facilities in China about their thermal sensation during summer. Several comfort parameters were also measured intending to find the correlation between the objective environmental indicators and the subjective environmental satisfaction of the users. The study concludes that the temperature range where the user feels thermally neutral, is above the range imposed by Chinese standards, therefore, users may be willing to accept a higher temperature range under certain conditions. Ortiz et al. (2019) performed a POE in a sports hall in Spain during the Mediterranean Games. Two monitoring campaigns collected data about thermal and visual comfort and air quality. The analysis allowed to find out that HVAC equipment was able to maintain the comfort users' needs except for relative humidity, which was over 60% during most of the time. The CO2 concentration measured inside the sports hall was almost all the time under the established levels by Spanish regulations. G.Revel and Arnesano (2014) went one step further and presented a thermal comfort monitoring methodology for sports centres. The methodology's scope is the collection of significant information on how energy is being used related to the comfort level perceived by users. Through an uncertainty analysis, they highlighted that the uncertainty of the PMV comfort calculus of a gymnasium is higher than in any other space, mostly, because of the metabolic rate estimation, which is a parameter that can vary greatly among the different users due to the different types of activities being performed in the same environment. A sensitivity analysis of the methodology showed that, among other parameters, low air velocities have a low influence in the PMV calculation.

This study contains first an overview of the different types of sports rooms, different existing comfort regulations and post-occupancy evaluations available in the literature. The second part contains the results of an indoor environmental monitoring campaign of a weight room in a gymnasium in Barcelona, which was performed based on the information collected and the literature review. The conclusions summarize the lessons learnt during the fieldwork.

2. Methodology

The regulations reviewed were carefully selected to gather insights from various countries and climates. The following criteria were considered during the research and source selection process:

- Primarily, the focus was on official regulations that hold legal value regulations on Indoor Environmental Quality (IEQ.
- Secondly, the research explored publications from reputable governmental entities or internationally recognized centres.
- The selected sources were required to have at least one specification related to thermal comfort and preferably cover additional aspects such as humidity, air quality, and luminous and acoustic comfort.
- As the revision was conducted in Spain, the research delved into analyzing regulations issued by different Autonomous Communities at the local level.
- The research considered the diverse climates based on the classification provided by the European Environment Agency (2012): Subtropical, Temperate, and Cold. Consequently, sources from countries representing each of these climates were examined.

To evaluate indoor environmental comfort inside the weight room, a two-weeks monitoring campaign of indoor environmental parameters and a comfort survey were performed. The selected sport centre is located in Barcelona close to the beach. The selected rooms fall into the category Room with equipment of the CEEC (see Table 1).

The positioning of the sensors has been selected according to the room distribution and together with the manager's input. Sensors have been installed at a height midway up the rooms. Since the weight room spans two floors and features a central area with double height, one sensor has been placed on the ground floor while the other has been installed on the elevated level. The sensors used for this monitoring are two types: COMET U3430, which is used to record temperature, relative humidity and CO2 and Elitech RC-5 or RC-5+ for temperature. Both have battery and data loggers recording every 2 min. Technical specifications are listed in Table 2.

Table 2: Measurement range, accuracy and resolution of the sensors used (Comet, Elitech, n.d.).

Sensor	Measure	Accuracy	Resolution
COMET U3430 (CO2)	0 | 5000 ppm	±50 ppm +3%	1 ppm
COMET U3430 (Temperature)	-20 | +60º C	±0.4º C	0.1º C
COMET U3430 (Rel. Humidity)	0 | 100 %	±1.8 %	0.1 %
Elitech RC-5 or RC-5+	-30 | +70º C	±0.5º C	0.1º C

The survey includes questions about thermal comfort, lighting, and air quality. To contrast the results of monitored data with the perception of occupants, these two must be collected at the same time. For this reason, the survey was conducted in digital format, with a QR code that, when scanned, led to a Microsoft Forms web page. Posters with the codes were located in the monitored rooms. In doing so, responses were collected at different times over the two weeks of monitoring.

3. Results

This section includes the results from both the regulations review and the monitoring campaign.

3.1 Regulations review

The "Quadern pràctic n 6" from ICAEN (2012) recommends a winter season comfort range of 16-18ºC and 40-60% relative humidity for sports rooms based on the French regulation (Ministre de l'industrie, 1977). These lower temperatures are justified by the higher metabolic rate of people during sports activities. In contrast, the regulation NIDE 1 by Consejo Superior de Deporte in 2021 recommends a temperature range of 20-23ºC (ideally 21.5ºC), similar to RITE (Asociación Técnica Española de Climatización y Refrigeración, 2012), without mentioning relative humidity. RITE requires a minimum air quality category called IDA 3 in all sports facilities, which entails fresh renovation airflow of 6-10 l/s per occupant and a maximum CO2 concentration of 800 ppm over outdoor concentration. For visual comfort, UNE-EN 12193-2009 specifies a minimum of 300 lux during training and 500 lux during competitions for sports halls, rooms, and courts.Other countries from the Mediterranean region present similar comfort requirements.

For instance, the current regulation from Italy written by CONI in 2008 requires a temperature range of 16-20ºC and relative humidity of 50% in closed sports rooms. The minimum lux required by the regulation are 300 for not competitive gymnastics (it increases to 500 lux in case of being competitive) and a minimum fresh renovation airflow of 5.5 l/s per occupant, a very similar value to the Spanish RITE. Additionally, a maximum value of 40dB is permitted as ambient noise.

Greek regulation included in the Technical Instruction for the building's efficiency (TOTEE-1) (ΚΛΙΜΑΤΙΚΗΣ, 2014) differentiates temperature and humidity depending on the season. During summer, the temperature and relative humidity recommended are 25ºC and 45% respectively, whereas during the winter these values decrease to 18ºC and 35%. The minimum lux specified for closed interior rooms for sports practice is 300 measured at 0.5 m from ground level. The minimum fresh renovation airflow per occupant is 12.5 l/s, equivalent to an IDA 2 level from RITE.

The guide of regulations for interior conditioning and ventilation in buildings developed by the Finnish Ministry of the Environment Housing and Building Department in 2003 specifies lower interior room temperatures compared to the previously mentioned ones (18ºC), while similar relative humidity (45%). Regarding the indoor air quality, the guide states a maximum limit of 1200 ppm of CO2 concentration that cannot be surpassed under any circumstance. The fresh renovation airflow should be 6 l/s per occupant, which can be reduced as the size of the facility increases. Also, similarly to the Italian regulations, the maximum noise is limited to 38-43 dB.

"Fitness and Exercise Spaces" from Sport England and S&P Architects (2008) by the English Sports Council have specific guides for fitness and indoor activities room. The temperature range recommended coincides with the one of the ICAEN (16-18ºC). However, in "Sports Halls Design & Layouts (Sport England et al., 2012), they consider the possibility that whenever the type of activity" is less physically intense the temperature should increase to 20ºC. Relative humidity should be kept below 60%. Optimal ventilation might be equivalent to a minimum of 20 l/s per occupant of fresh renovation airflow during the maximum influx hours. For visual comfort, the guide recommends a minimum value of 300 lux and the noise should be kept under 40 dB.

The US American College of Sports Medicine (ACSM, 2012) published a series of guides for design and operation of sports centres, with special emphasis on fitness rooms. It is indicated that relative humidity should be kept under 60% or ideally 50% and the ambient temperature around 20-22ºC. It is also mentioned that air quality needs to be maintained through the fresh renovation

air introduction but the quantity per occupant is not specified. Regarding visual comfort, the guide recommends at least at 500 lux measured at eye height. In regards to ambient noise, the guide does not indicate which is the appropriate level that may need to be maintained, however, it is pointed out that noise can reach up to 80-90 dB in this kind of space and therefore, it is required the introduction of measures to reduce it.

The European Gymnastics Federation (2022) based in Switzerland, recommends in its medical guidelines that athletes who practice this sport modality never surpass a score of 39 (equivalent to a relative humidity of 55% and an ambient temperature of 31ºC) on the humidex scale. The humidex is a dimensionless quantity that describes how hot, humid weather feels to the average person, combining temperature and humidity into one number to reflect the perceived temperature (Meteorological Service of Canada 2019). Similarly, the International Gymnastics Federation (2023) recommends maintaining the temperature and relative humidity levels within the range of a score of 22-38 on the humidex scale. This range of values is equivalent to a temperature between 21-31ºC and a relative humidity between 45-50%. The European Fencing Confederation (2022), based in Luxemburg indicates that rooms set aside for competition need to be maintained within 17-22ºC at any time. Table 3 shows the summary of data from all references consulted.

Table 3 Summary of comfort data for all the references reviewed.

Publication details	Thermal comfort		Air quality		Visual	Acoustic
(Author, Year)	Temperature (ºC)	Relative humidity (%)	Outdoor airflow (l/s per occ.)	CO_2 conc.(ppm)	Illumination (lux)	Noise (dB)
RITE (Asociación Técnica Española de Climatización y Refrigeración, 2012)	Summer: 23-25 Winter: 21-23	Summer: 45-60 Winter: 40-50	6-10	400+800	300	-
(ICAEN, 2012)	16-18	40-60	8	-	300	-
NIDE (Consejo Superior de Deportes, 2021)	20-23 (21.5)	-	-	400+700	300	-
(CONI, 2008)	16-20	50	5.5	-	300	40
(ΚΛΙΜΑΤΙΚΗΣ, 2014)	Summer: 25 Winter: 18	Summer: 45 Winter: 35	12.5	-	300	-
(Ministry of the Environment Housing and Building Department, 2003)	18	45	6	400+800	-	38-43
(Sport England, 2012)	16-18	<60	20	-	300	40

(American College of Sports Medicine, 2012)	20-22	<60	-	-	500	<80
(European Gymnastics, 2022)	<31	<55	-	-	-	-
(Fédération Internationelle de Gymnastique, 2023)	21-31	45-50	-	-	-	-
(European Fencing Confederation, 2022)	17-22	-	-	-	-	-

The data collected during the monitoring campaign, coming from both the sensors (temperature, relative humidity and CO_2 concentration) and the surveys (sensation of the occupants) are compared to different comfort ranges, taken from the list explained in Table 3. Not all of the identified ones where used for the comparison, as it would have caused confusion. The ranges selected for the comparison, listed in Table 4, are the ones with legislative value or from an important authority in the region (RITE and ICAEN), or of the most sports and health entity at local and international level (NIDE and ACSM).

Table 4: Temperature, relative humidity and CO_2 concentration ranges selected for comparison.

	Regulation	Range	Observation
Temperature	NIDE	20-23º C	With an ideal temperature of 21.5º C
	ACSM	20-22º C	
	ICAEN	16-18º C	For sports with a moderate metabolic activity (gymnastics, dance, kids, handball, basketball…)
Relative Humidty	ACSM	Under 60%	Always under 60%, ideally around 50%
	ICAEN	40-60%	
CO_2 concentration	NIDE	Under 700 ppm	Always to be calculated over the external air concentration.
	RITE	Limit IDA1 350 ppm Limit IDA2 500 ppm Limit IDA3 800 ppm Limit IDA4 1200 ppm	

3.1 Monitored data

Figure 1 shows the values of temperature collected by the sensors of the weight room. The grey areas refer to the ranges identified by the selected regulation. Each dot represents an answer to the survey, where the colour is the subjective thermal sensation and the position is determined by the time the user made it and the temperature recorded by the sensors. The two sensors indicate a temperature difference of up to 1.5º C, due to the thermal stratification. The thermometer at the

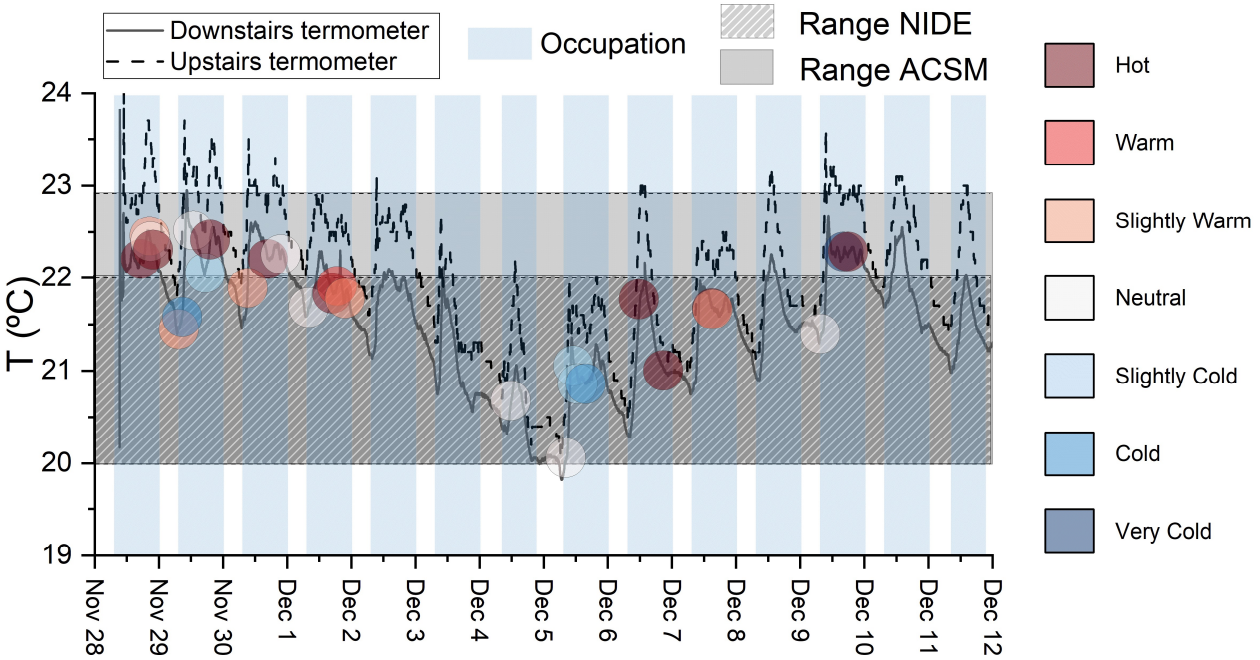
lower floor is usually inside the range suggested by the ACSM (2012), while the one at the upper floor, is still inside the range suggested by NIDE (Consejo Superior de Deportes, 2021). The light blue vertical bands refer to the occupied time (from 6:30 AM to 11 PM), when the room is open.

Regarding relative humidity NIDE is not mentioned between the selected regulations in Table 4 as it does not consider any range for it. Figure 2 shows that relative humidity is under 60% (with the exception of a few hours in the monitored period) and over 40% almost all the time, staying inside the range suggested by the NIDE.

For the CO_2 concentration the current study uses the NIDE and the RITE (Asociación Técnica Española de Climatización y Refrigeración, 2012), as listed in Table 4. As both the ICAEN (2012) and the ACSM does not mention any value for the CO_2. As explained in the introduction, this regulation establishes the level of IDA 3 for sports centres (800 ppm above outdoor level), while NIDE defines only one range of comfort (as it is focused on sports centres), under 700 ppm. Figure 3 shows the CO_2 concentration along the two weeks of monitoring campaign. The daily concentration fluctuates from the outdoor level (during the night) to peaks of up to 1500 ppm. The room is 91% of the occupied time (from 6:30 AM to 11 PM) inside IDA 3 limit, while, according to the NIDE, it is only 30% of the time inside the range.

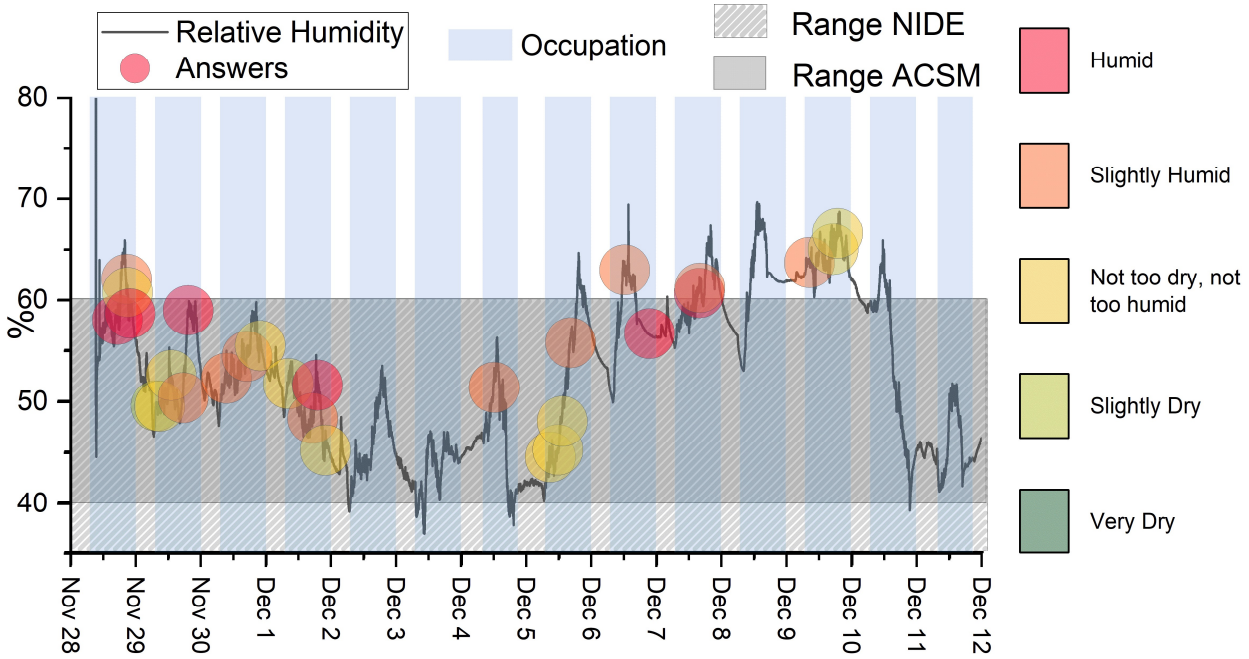
All the parameters looks like there is a correlation with the occupation. Indeed, they all tend to increase during the occupied time. In particular, temperature and CO_2 concentration present a first peak in the morning, and a second one in the afternoon, except for Sundays (Dec 4 and Dec 12) and holidays (Dec 6 and Dec 8), which have only one central peak. The most probable reason is the presence of occupants, but we do not have sufficient information to estimate the quantity for this room. Relative humidity, instead, has a more variable behaviour, as it is affected by temperature changes inside and outside the room, as well as absolute humidity.

Figure 1: Temperature data collected in the weight room.



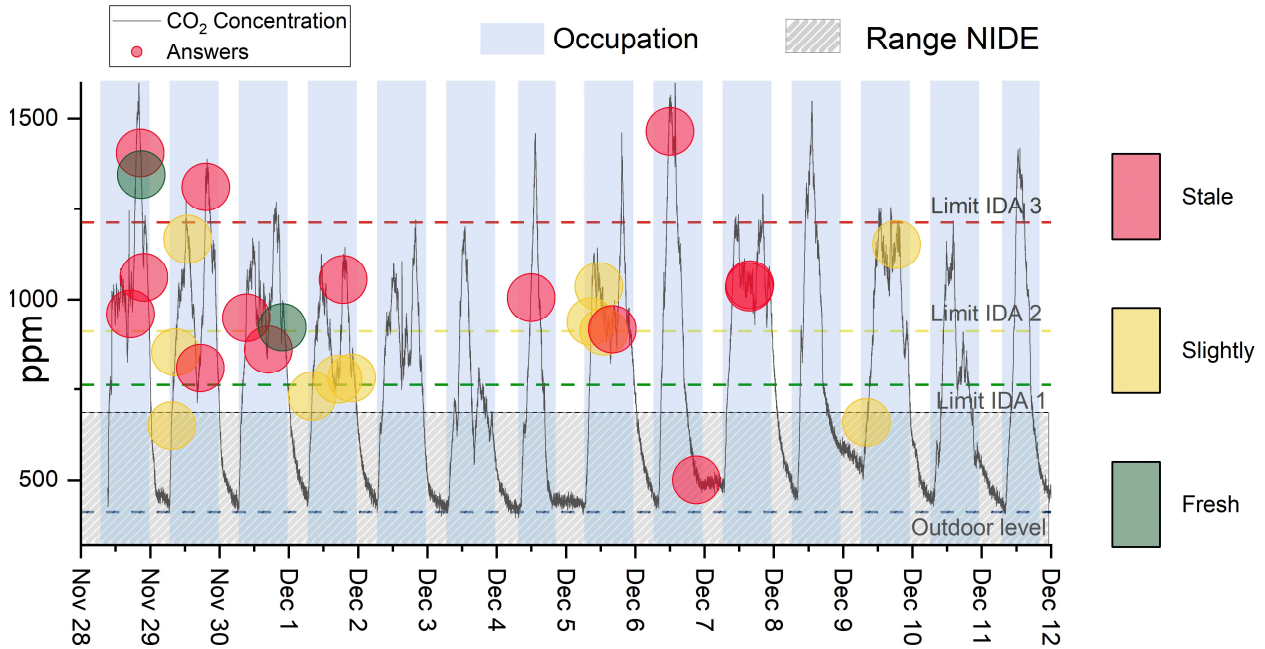
Note: The black lines refer to the temperature, while the circles represent answers of the survey. Colour depends on the perception about thermal comfort. Vertical light-blue bands refers to occupation periods.

Figure 2: Relative humidity data collected in the weight room.



Note: The black line refers to the relative humidity, while the circles represent answers to the survey. Colour depends on the perception about humidity. Vertical light-blue bands refers to occupation periods.

Figure 3: CO2 concentration data collected in the weight room.



Note: The black line refers to CO2 concentration, while the dots represent answers to the survey. Colour depends on the perception about the air quality. Vertical light-blue bands refers to occupation periods.

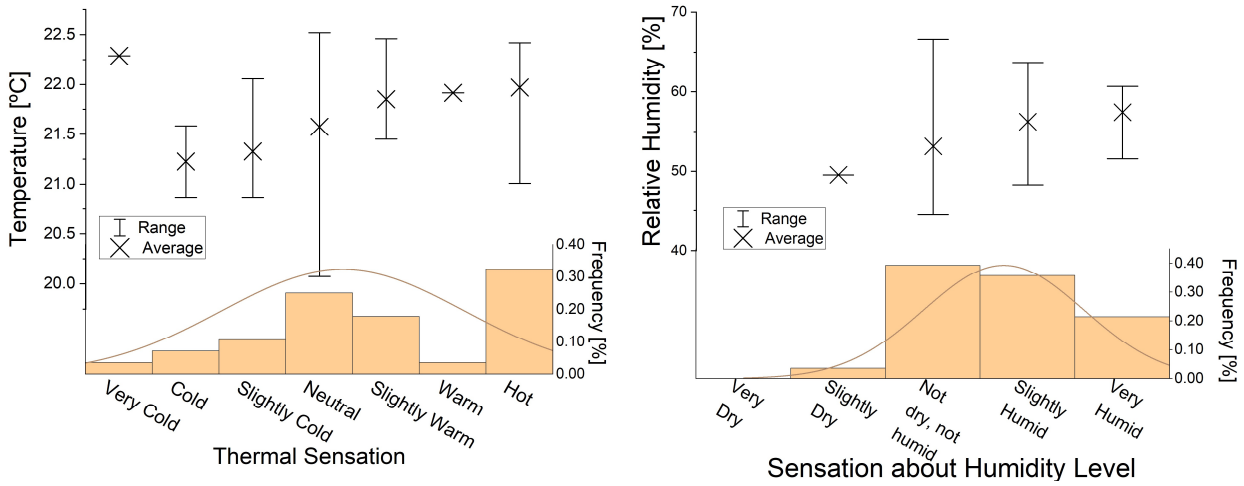
3.2 Correlation to Occupants' perception

Figure 4 displays the objective data range for temperature and relative humidity, respectively, collected for each level of sensation reported by participants in the weight room. The lower section of the graphs shows the frequency distribution of the responses. Interestingly, the neutral sensation elicited the widest range of temperature (approximately 20.0 to 22.5 ºC) and humidity (approximately 45% to 65%) perceptions. The crosses on the graph indicate the average values recorded for each level of sensation. The thermal sensation crosses exhibit a general increasing pattern, indicating that individuals felt colder at lower temperatures and warmer at higher temperatures, with the exception of the "Very Cold" sensation, which was reported only once and for a quite high temperature. Collecting a larger sample of responses helps to reduce the impact of individual opinions on the overall average. Similar observations were made for humidity perception; individuals' perceptions aligned with the objective data.

The normal distribution of responses for thermal sensation falls between "Neutral" and "Slightly Warm," but, "Hot" received the highest number of votes, representing more than one-third of all responses. Similarly, the normal distribution of responses for humidity has a peak at "Slightly Warm," but the most commonly selected response was neutral: "Not too dry, not too humid".

In general, people in the room tended to give more answers on the right of the scales, than on the left. This might happen because of the sports activities they were doing. This fact suggests that even in winter, the most common problem in fitness rooms is the sensation of heat and humidity.

Figure 4: Range of temperatures (left) and relative humidity (right) collected at the instant of the answers, divided by type of answer.



Note: The upper part of the graph represents the ranges of objective data for each type of answer on thermal and humidity sensation. The lower part refers to the frequency of answer.

4. Conclusions

The study makes a review of regulations about thermal comfort and Indoor Air Quality (IAQ) for sport rooms and explains the results of a monitoring campaign of a sport facility. The objective is to expand knowledge on the regulations and get a deeper understanding of sports buildings.

Regulations regarding thermal comfort and air quality for sports centres vary from country to

country, and not always agree on the same parameters. Some of them, like Spain do not have a specific regulation for sports centres. While there is a wider range of suggested values for comfort temperatures (from 16 to 31 ºC), numbers for relative humidity are similar (maximum 60, usually recommended is between 40 and 50%). CO2 concentration for air quality is rarely considered. Some regulations distinguish between summer and winter values, and take into account more aspects of environmental comfort than just temperature or humidity. Although recommendations might vary from country to country depending on the climate adaptation of the people (Kong, 2019), traditions and typical weather (which influence thermal comfort), there are some objective parameters which can be measured easily and could help uniform the way of regulating. Metabolic rate of the activities, and clothing of people, as described by Fanger in 1970 in his comfort model, play a role in thermal sensation. For example, classifying different sports activities based on the metabolic rate and clothing of people might be helpful to avoid any incertitude around whether the regulation is applicable or not in the considered room/situation. Increasing the level of detail of regulations and differentiating between kinds of activities might help address correctly all the situations that happen inside rooms in sports facilities.

Temperature in the monitored room are in accordance mainly with NIDE (Consejo Superior de Deportes, 2021) (20-23º C) and the range suggested by ACSM (2012) (20-22º C), while it usually keeps itself quite far from the lower range suggested by ICAEN (2012) (16-18º C). Relative Humidity instead, has regulations more in accordance with each other, and the monitored values where most of the time below 60%, as recommended by NIDE and by ACSM. CO2 concentration is kept for most of the time inside the range suggested by RITE (Asociación Técnica Española de Climatización y Refrigeración, 2012), while it looks more unrealistic to stay inside the range recommended by NIDE. When trying to correlate the thermal sensation with the objective data collected, it looks like the neutral sensation averagely happens to be at 21.6º C, while the neutral sensation on humidity levels is recorded at 53,1 %. Both stay inside the respective regulations.

Nevertheless, the thermal perception of people is influenced by several causes of incongruence, such as metabolism rate, age, air velocity, type of activity and clothing. Crossing objective data with people's perception allows increasing knowledge on this field and possibly finding better parameters for thermal comfort, developing more detailed protocols for rooms in sports facilities. This paper aims to establish the foundation for further research by gathering data on objective parameters and people's perception through monitoring sports facilities and surveying their occupants. By collecting data from rooms where various activities are practiced, it is possible to understand the differences in comfort parameters among sports activities that involve varying metabolic rates, intensity levels, and clothing.

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6. Communication aligned with the Sustainable Development Objectives