Indoor particulate pollution in fitness centres with emphasis on ultrafine particles ☆

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A B S T R A C T

Fitness centres (FC) represent a unique indoor microenvironment. Exercising on regular basis provides countless health benefits and improves overall well-being, but if these facilities have poor indoor air quality, the respective exercisers might be subjected to some adverse risks. Considering the limited existent data, this work aimed to evaluate particulate pollution (PM_{10}, $PM_{2.5}$, and ultrafine particles – UFP) in indoor air of FC and to estimate the respective risks for occupants (both staff and exercising subjects). Sampling was conducted during 40 consecutive days of May–June 2014 in general fitness areas, studios and classrooms (for group activities) of four different fitness centres (FC1–FC4) situated within Oporto metropolitan area, Portugal. The results showed that across the four FC, PM_{10} ranged between 5 and 1080 $\mu g\ m^{-3}$ with median concentrations (15–43 $\mu g\ m^{-3}$) fulfilling the limit (50 $\mu g\ m^{-3}$) of Portuguese legislation in all FC. $PM_{2.5}$ (medians 5–37 $\mu g\ m^{-3}$; range 5–777 $\mu g\ m^{-3}$) exceeded thresholds of 25 $\mu g\ m^{-3}$ at some FC, indicating potential risks for the respective occupants; naturally ventilated FC exhibited significantly higher PM ranges ($p < 0.05$). Similarly, UFPs (range $0.5–88.6 \times 10^3$ # cm^{-3}) median concentrations were higher (2–3 times) at FC without controlled ventilation systems. UFP were approximately twice higher ($p < 0.05$) during the occupied periods (mean of 9.7×10^3 *vs.* 4.8×10^3 # cm^{-3}) with larger temporal variations of UFP levels observed in general fitness areas than in classrooms and studios. Cardio activities (conducted in studios and classrooms) led to approximately twice the UFPs intakes than other types of exercising. These results indicate that even short-term physical activity (or more specifically its intensity) might strongly influence the daily inhalation dose. Finally, women exhibited 1.2 times higher UFPs intake than men thus suggesting the need for future gender-specific studies assessing UFP exposure.

Keywords:
Indoor air
Particulate matter (PM)
Ultrafine particles (UFPs)
Fitness centers
Inhalation intake

1. Introduction

The recent estimates have shown that approximately 30% of the worldwide adult population is insufficiently active (Hallal et al., 2012) causing premature mortality (5.3 out of 57 million deaths that occurred worldwide in 2008; Lee et al., 2012) as well as increased risks of various diseases (coronary, heart, type 2 diabetes, breast cancer, colon cancer and etc.; Lee et al., 2012): more than 1.3 million deaths could be averted every year if inactivity was reduced by 25% (Lee et al., 2012). At the same time, overweight and obesity rates have been rising with more than 50% of European adult population (aged ≥ 20 years) being overweight or obese, which annually results in about 320 000 deaths (WHO, 2015). For improved health benefits, World Health Organization (WHO) recommends minimum of 150 min of moderate-intensity of aerobic physical activity per week for adults (WHO, 2016). In order to stay healthy, people frequent fitness centres and gyms. Compared to other indoor spaces (such as offices or homes), these represent a unique indoor microenvironment (Andrade et al., 2017; Revel and Arnesano, 2014) where, due to increased inhalations (from physical activities), occupants might be exposed to higher risks of some relevant indoor pollutants (Alves et al., 2014; Andrade et al., 2017;

Ramos et al., 2015).

Overwhelming scientific evidence has shown that exposure to ambient particulate matter (PM), namely PM_{10} (aerodynamic diameter < 10 μm) and $PM_{2.5}$ (<2.5 μm) is associated with increased mortality rates, in particular with deaths from cardiovascular and respiratory diseases (Amato et al., 2014; Beelen et al., 2015; Brook et al., 2010; Holgate, 2017). PM is a complex mixture of particles of different sizes including ultrafine particles (UFPs) that are typically designated as those below 100 nm in aerodynamic diameter. UFPs contribute only little to overall PM mass but dominate the number concentrations. Therefore, unlike for PM_{10} or $PM_{2.5}$, the typically used metric is not mass concentrations (μg cm^{-3}) but particle number concentrations (# cm^{-3}) though some studies suggest particle surface area (Kumar et al., 2014; Wichmann et al., 2000). UFPs originate naturally via atmospheric formations (Heal et al., 2012) or from anthropogenic sources (combustion by-products from power plants, ship and aircrafts exhausts, construction processes, biomass burning, fuel combustion, waste incineration, agriculture processes; Heal et al., 2012), with road traffic being by far the most significant contributor of UFPs in urban areas (Carpentieri et al., 2011; Kumar et al., 2013). Indoors, UFP are emitted from primary indoor sources (Cavaleiro Rufo et al., 2016; He et al., 2004, 2007; Morawska et al., 2013; Kumar et al., 2013; Voliotis et al., 2017) but human activities, such as the use of cleaning products, may result in formation of a wide range of secondary particulates (Rossignol et al., 2013); other studies reported outdoor emissions as the important contributor to indoor number particles (Quang et al., 2013; Tippayawong et al., 2009). Due the higher occupants' density and the lesser degree of dilution or particle dispersion (Hodas et al., 2016; Nazaroff, 2004), exposures to UFPs in indoor spaces might be larger than when outdoors (Śek ö et al., 2015b; Mazaheri et al., 2014; Morawska et al., 2013; Reche et al., 2014; Rivas et al., 2014). Inhalation is the major route of human exposure to UFP though dermal exposure cannot be excluded (Mancebo and Wang, 2015). UFPs are highly biologically active (Lee et al., 2014; Terzano et al., 2010) and more toxic and inflammatory than $PM_{2.5}$ (Chen et al., 2016), mostly for two reasons. Firstly, the small size of UFPs allows penetration into the deepest parts of respiratory system (human alveolar macrophages are incapable of removing particles < 70 nm; Bakand et al., 2012) and possibly enter the blood stream (Bakand et al., 2012; Heal et al., 2012). Secondly, due to the larger total surface area (in comparison with PM_{10} or $PM_{2.5}$), UFPs can carry other toxic pollutants (such as heavy metal elements, organic gases) and interact with lung cells (Chen et al., 2016). In view of these aspects, some researchers argued that UFPs might be responsible for the documented adverse health effects of $PM_{2.5}$ (Heinzerling et al., 2016; Terzano et al., 2010). Cardiovascular and pulmonary effects in adult population have been linked with exposure to UFPs but the epidemiologic evidence is far from comprehensive (McCreanor et al., 2007; Heinzerling et al., 2016; Zhang et al., 2009). In addition, UFPs have been linked with increased morbidity (Andersen et al., 2008; Halonen et al., 2008) and respiratory mortality (Chen et al., 2016; Heinzerling et al., 2016).

Overall, the information on indoor air quality in fitness centres is somewhat limited, both in terms of the respective exposures and public health risks. The rather limited data on PM comes from two main types of sport environments: non-educational sport facilities (such as fitness centres and sport halls) and educational settings (such as elementary/primary school gymnasiums or sport facilities from universities). Majority of the studies were conducted in the latter (Alves et al., 2013, 2014; Braniš et al., 2009, 2011; Braniš and Šafránek, 2011; Buonanno et al., 2012a; Castro et al., 2015; Fonseca et., 2014; Kic, 2016; Szoboszlai et al., 2011; Ward et al., 2013; Žitnik et al., 2016), mostly due to the better possibility to control the respective environments during the experiment, whereas only few previous studies have assessed indoor PM in the non-educational sport facilities (Filipe et al., 2013; Saraga et al., 2014; Weinbruch et al., 2012) or fitness centres (Almeida et al., 2016; Ramos et al., 2014; Onchang and Panyakapo, 2016); none of the studies addressed UFPs levels. Furthermore, fitness centres have different purposes from those of school (or university) gymnasiums and competing-sport halls, and thus very specific characteristics (in terms of layout and construction materials, occupants, type of activities, daily patterns or even frequency of operation; Revel and Arnesano, 2014). Therefore, the existing data might not be applicable for the respective exposures in fitness centres. In addition, the wide range of physical activities conducted in the fitness centres and different physicality between both male and female genders will further impact on the respective exposures.

Considering the lack of information mainly in regards with ultrafine particles this work evaluated indoor particulate pollution of fitness centres and estimated the potential risks during exercise activity. Levels of particulate matter (PM_{10} and $PM_{2.5}$) and UFPs in indoor air of four fitness centres were assessed. In addition, the inhalation doses were estimated for the occupants (both staff and exercising subjects) considering different physicality of male and female genders and various scenarios of physical activities (cardio and holistic classes).

2. Material and methods

2.1. Sampling sites description

The sampling was conducted consecutively in four different fitness centres (FC1–FC4) during 40 days (May–June of 2014). All facilities were fitness centers and they were all situated within the Oporto metropolitan area (Portugal). Fitness centers were situated in urban zones where the main air pollution sources were road traffic and industrial emissions (Pereira et al., 2007). FC1 and FC2 were simple and small-size sport facilities. Apart from fitness area (a combined space for cardiovascular equipment such as treadmills, elliptical, stationary bikes, and for bodybuilding spaces for free weights and machines), these two gyms had only one classroom for group activities. FC3 and FC4 were large fitness centers (~400 up 1000 visitors daily). Apart from a large fitness space, 3 studios for group classrooms for holistic (yoga, pilates, stretching, etc.), aerobic and cardio muscular activities, both these centers had an indoor swimming pool, spas, and beauty/health-care areas. Detailed characterizations of all fitness centers are provided in Table 1, with photographic demonstrations in Fig. 1S.

2.2. Particle collection

In each fitness centre, the sampling was carried out continuously (24 h) during all week days (Mon–Fri) and weekends (Sat–Sun). All equipment was positioned on supports (approximately at 1.4 ± 0.2 m above the floor surface) and at least 1.5 m from walls to minimize the influence on particle dispersion (Holmberg and Li, 1998; Jin et al., 2013) and avoiding all direct emission sources that might interfere with data acquisition (i.e. air conditioners, ventilation points through windows and doors). Necessary measures were taken in order to keep the safety of exercising subjects. One TSI P-Trak™ condensation particle counter (model UPC 8525; TSI Inc., MN, USA) was used for real-time measurement of UFP particle number concentrations (size range N 20–1000 nm; up to 5×10^5 particles cm^{-3}) with an intake flow of 0.7 L min^{-1}. Sampler was calibrated prior to the sampling campaign by the manufacturer. To verify its normal operation, the zero readings of the instrument were checked daily (based on the manufacturer

Table 1
Characterization of the four studied fitness centres (FC1– FC4).

	FC1	FC2	FC3	FC4
Year of constructions	2008 refurbished in 2012	2007	2006 new installations in 2008	2007
Location	Residential area; Situated on ground level in residential building (with 3 floors)	Suburban zone; Situated on ground level in main building of university campus; gym entrance directly faces a road (~10 m)	Residential area; Situated in lower ground floor in a block of flats (with 4 floors); local traffic road	Situated on 2nd floor in large shopping centre; close a major international highway; Club situated directly next to large restaurant/eating area
Site characterization	Urban	Urban	Urban	Urban
Outdoor emissions sources	Traffic Density: 144–414 vehicles per hour (peak hours: 13:30; 18:30)	Traffic Density 456–1338 vehicles per hour (peak hours: 17:30; 20:00)	Traffic Density 138–402 vehicles per hour (peak hours: 13:30; 18:30)	Traffic/industrial No expected impact of traffic emissions due to the interior situations (inside of a shopping mall)
Gymnasium description	Small-size facility with 1 classroom for group activities and 1 general fitness space (a combined area for cardiovascular equipment, machines and free weights); 2 locker rooms; reception counter, and 2 small storage rooms	Small-size facility; 1 room for group classes and 1 fitness space; sauna; 2 locker rooms; reception counter and 1 storage room	Fitness health club with 3 studios for group exercises; fitness space (cardiovascular + weights); indoor swimming pool and hot tub; 1 physical therapy room; 3 locker rooms; reception area and storage rooms	International-brand health club with 3 classrooms for group exercises; fitness space (cardiovascular + weights); indoor swimming pool and spa facilities; beauty and physical therapy rooms; 2 locker rooms; reception area and storage rooms
Building main construction materials	Brick, concrete, ceramic tiles, wood	Brick, concrete	Brick, concrete, ceramic tiles, wood	Brick, concrete, ceramic tiles, wood
Occupancy (clients per day)	~191–265; Peak: 10–11 a.m.; 8–9 p.m. Minimum: 8–9 a.m.	~118–246; Peaks: 12 a.m.–1 p.m.; 5–7 p.m. Minimum: 8–9 a.m.	~250–410; Peaks: 12 a.m.–1 p.m.; 6–8 p. m. Minimum: 8–9 a.m.	~ up 1000 Peaks: 11 a.m.–1 p.m.; 8–10 p.m.; Minimum: 2–3 p.m.
Heating systems	None	None	None	None
Ventilation	Natural + air supply On daily basis mainly purge ventilation through opened windows	Natural + air conditioning system (maintenance in March 2014)	Controlled ventilation: Forced ventilation with centrifugal fan and air conditioning with in/out pipe machines (cleaned on 23 May 2014)	Controlled ventilation: Forced ventilation with centrifugal fan and air conditioning with in/out pipe machines (maintenance on 5 May 2014)
Cleaning	During lunch period (1 p.m.–2 p.m.) on some occasions during off–hours;	During off hours only	Before clubs opened; at night and continuously throughout the day; after each class	Before clubs opened; at night; continuously throughout day; after each class
Working hours	Mon–Fri: 8 a.m.–10 p.m. Sat: 9 a.m.–8 p.m. Closed during lunch period (1 p.m.–2 p.m.)	Mon–Fri: 8 a.m.–10 p.m. Sat: 10 a.m.–1 p.m.	Mon–Fri: 7 a.m.–10 p.m. Sat: 9 a.m.–8 p.m. Sun: 9 a.m.–2 p.m.	Mon–Fri: 7 a.m.–10 p.m. Sat: 9 a.m.–8 p.m. Sun: 9 a.m.–6 p.m.
Dimensions:				
Fitness area				
Area (m^2)	134	135	163	626
Height (m)	3.0	3.7	4.3	4.0
Classrooms for group activities	1	1	3	3
Area (m^2)	4 8	7 5	8 9	5 8
Height (m)	3.0	3.7	3	4.0

recommendations) when exchanging the working fluid. Further detailed characterization of the sampler has been previously reported (Matson, 2005; Matson et al., 2004). PM_{10} and $PM_{2.5}$ were monitored by portable TSI DustTrak DRX photometers (model 8533; TSI Inc., MN, USA; range up to 150 × 10^3 μg m^{-3}, accuracy ± 0.1% of reading of 1 μg m^{-3}) using a flow rate of 3.0 L min^{-1}. The photometer was calibrated at the factory and it was daily (beginning of the day) automatically zeroed (using external zeroing module) in order to minimize the zero drift which might help avoiding the occurrence of sudden artefact jumps in PM concentrations (Rivas et al., 2017). Both UFP and PM were collected continuously (during 24 h) in all fitness centres with logging intervals of 1 min (i.e. measurements done every second with an average value per minute being recorded); each day approximately 1400 values were obtained. In each FC, various indoor spaces (fitness area, group classrooms and studies) were consecutively analysed. Indoor temperature and relative humidity were recorded (Table 1S of Supplementary material); ambient meteorological parameters (Table 2S) were obtained from the local meteorological stations, whereas concentrations of PM in ambient air were retrieved from the air quality monitoring network of Portuguese Environmental Agency (Table 3S).

A member of the research team was daily on-site (during the opening hours) to register relevant information such as occupancy (classrooms for group exercises, studios and fitness area), cleaning patterns (time and procedures), and any pertinent information related to ventilation and potential sources. When necessary, staffs of each fitness centre provided further details.

2.3. Inhalation dose calculations

The inhalation doses were calculated according to Equation (1) (Castro et al., 2011; Fonseca et al., 2014):

$$\text{Dose (D)} = (BR/BW) \times C \times t \qquad (1)$$

where D is the age-specific dose (#kg $^{-1}$); BR is the age-specific breathing rate (L min^{-1}); BW is age-specific body weight (kg); C represents median concentration of UFPs in the respective indoor spaces (# L^{-1}); t is time of exposure (min).

The inhalation doses were estimated for the different exposure scenarios: i) holistic classes (such as pilates, yoga, stretching) conducted in studios/group classrooms which involved balance, strength and flexibility training; ii) group cardio classes (circuit training, body pump, total conditioning) that included both vigour cardiovascular exercising and strength training, iii) individual fitness training conducted in fitness area; and iv) occupational exposure (for employees and fitness instructors). The duration of physical activities was 50 min for group classes, 60 min for training in fitness areas, and 8 h for the assessment of the professional staff. Each type of activity was characterized in terms of the physical intensity with the gender-(male and female) and age-specific (21 to <31yrs. old; 31 to <41; and 41 to <51) parameters (BR, BW) retrieved from USEPA (USEPA, 2011). An example of the inhalation dose calculation is presented in Table 4S.

2.4. Statistical analysis

The statistical analyses were conducted using Microsoft Excel 2013 (Microsoft Corporation), SPSS (IBM SPSS Statistics 20) and Statistica software (v. 7, StatSoft Inc., USA). As obtained data did not display the normal distributions (confirmed by Shapiro–Wilk's test), medians were compared through the nonparametric Mann–Whitney *U* test. Statistical significance threshold was set as $p < 0.05$.

3. Results and discussion

3.1. PM_{10} and $PM_{2.5}$ mass concentration

Overall, indoor levels of PM_{10} and $PM_{2.5}$ in all four fitness centres (Fig. 2S; Table 3S) showed much higher concentration ranges that the respective levels in the ambient air, particularly at the smaller fitness centres. At FC1, indoor PM_{10} concentrations were between 5 and 459 μg m^{-3} (median of 43 μg m^{-3}), whereas this range was even higher (6–1080 μg m^{-3}; median of 22 μg m^{-3}) at FC2. The corresponding levels of indoor $PM_{2.5}$ were in similar ranges: 5–285 μg m^{-3} (37 μg m^{-3}) at FC1 and 6–777 μg m^{-3} (15 μg m^{-3}) at FC2; whereas for ambient air the obtained levels were much lower (1–50 μg m^{-3} and 1–51 μg m^{-3} for PM_{10} at FC1 and FC2, respectively; 1–24 μg m^{-3} and 1–21 μg m^{-3} for $PM_{2.5}$ at FC1 and FC2). Furthermore, the indoor PM ranges in FC1 and FC2 were significantly higher ($p < 0.05$) than in fitness centres FC3–FC4 where the obtained indoor levels were much lower: PM_{10} of 11–95 μg m^{-3} (median of 22 μg m^{-3}) and $PM_{2.5}$ of 11–76 μg m^{-3} (19 μg m^{-3}) at FC3; at FC4 the obtained ranges were 6–106 μg m^{-3} (15 μg m^{-3}) for PM_{10} and 5–104 μg m^{-3} (15 μg m^{-3}) for $PM_{2.5}$ (Fig. 2S). Although FC1 and FC2 were daily frequented by lower number of exercising subjects, these two fitness clubs were mainly ventilated by opening windows, which might reflect in the overall higher indoor levels of PM. In addition, both these fitness centres were situated on the ground floor of the trafficked streets with the windows (fitness area/group classrooms) directly facing the traffic emissions. On the contrary, health clubs FC3 and FC4 used ventilation systems (and filtration of air before its supply to the building), which led to a reduction of outdoor particles infiltrations. In agreement, for these two FC ambient PM_{10} levels were significantly ($p < 0.05$) higher (median of 23 and 21 μg m^{-3} at FC3 and FC4; Table 3S) than those indoors, whereas this was not the case for the FC1–FC2 that were naturally ventilated. Similarly, previous studies reported higher penetration of outdoor PM through open windows indoors under natural ventilation conditions than when using mechanical ventilations (Montgomery et al., 2015; Loupa et al., 2007).

PM levels according to the occupancy periods (i.e. during the opened hours and when closed) are presented in Fig. 1. At FC1–FC3 higher PM concentrations ($p < 0.05$) were registered during the occupied periods. These differences were especially noticeable at FC2 where, on some occasions during the periods of exercising, PM_{10} and $PM_{2.5}$ were up to 16 and 12 times higher, respectively, than when vacant (medians: 26 μg m^{-3} and 22 μg m^{-3} for PM_{10} and $PM_{2.5}$ during the occupied *vs.* 20 μg m^{-3} and 19 μg m^{-3} for non-occupied; $p < 0.05$) mostly due to combined effects of occupants activities (Žitnik et al., 2016), natural ventilations (i.e. infiltration of ambient air emissions; Fonseca et al., 2014) and buildings characteristics (Madureira et al., 2016). At FC1 and FC3, the observed differences between both periods were lower, with PM up to twice higher during the occupied periods. In addition, it is necessary to point out that at FC1 two events with high PM increases (3–5 times in comparison with other centres) were registered during the vacant periods due to cleaning activities (vacuuming rubber floor carpeting; Table 1) done during the nocturnal time (around 23:00). The respective PM_{10} and $PM_{2.5}$ concentrations in FC1 increased approximately 5 times during the first night of sampling and 6 times during the fourth night of sampling when compared with the average PM concentrations of this indoor place; similarly, Ramos et al. (2014) reported 6–8 times increased PM_{10} levels due to floor cleaning activities. FC4 was the only venue with an increased median PM concentrations during the nocturnal periods when the gym was vacant: from 15 *vs.* 21 μg m^{-3} for PM_{10} and 15 *vs.* 19 μg m^{-3} for $PM_{2.5}$. Alves et al. (2014) also reported significant increases of mostly fine particles concentrations during the night (i.e. when empty) at sport facilities. The authors assumed formation of new aerosols caused by oxidation of volatile organic compounds (Ortega et al., 2012) emitted from late-afternoon cleaning. Increased levels of particles during night time periods (with no active indoor sources or human activity) were also observed in indoor air of offices (Moliniè et al. (2011). These authors assumed combined effect of penetration of outdoor emissions and their accumulation due to the motionless conditions that prevented mixing.

In terms of the existent data in non-educational indoor sport environments (Table 2), particularly high levels were reported for gymnastics halls (PM_{10}: 658–716 μg m^{-3}; $PM_{2.5}$: 170–500 μg m^{-3}; Filipe et al., 2013) and climbing centres (up to 160 and 1180 μg m^{-3} for $PM_{2.5}$ and PM_{10}, respectively; Weinbruch et al., 2012) due to the frequent use of magnesium chalk (for drying hands and a better grip). In two previous studies (Almeida et al., 2016; Ramos et al., 2014, 2015), indoor air quality of 11 fitness centres (Lisbon; majority centres with mechanical ventilation) was assessed with short-term measurements (45–60 min) conducted during the busiest hours. The authors reported concentration ranges (PM_{10}: 1.8–153 μg m^{-3}; $PM_{2.5}$: 0.9–43 μg m^{-3}), which were in similar ranges as in FC3 and FC4 (i.e. centres with controlled ventilations; Fig. 1). Different ventilation systems (i.e. outdoor infiltrations) at FC1 and FC2, dissimilar monitoring protocols in the studies as well as seasonal influence might be responsible for the observed differences of indoor PM levels (Morawska et al., 2013) at FC1 and FC2.

The results in Table 3S show that over the considered period, PM_{10} levels in ambient air (6–41 μg m^{-3}) did not exceed the EU

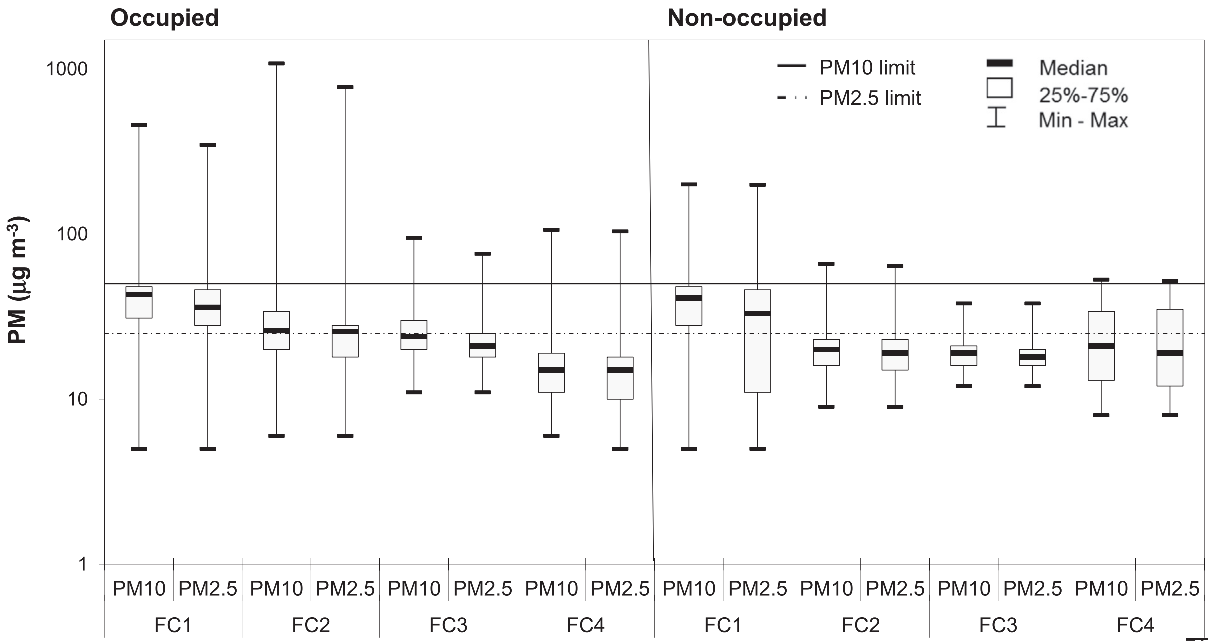

Fig. 1. PM_{10} and $PM_{2.5}$ levels (■ median; □ 25–75%, and ⌶ range) at four fitness centres (FC1– FC4) during: occupied and non–occupied periods. The horizontal lines represent Portuguese limits (Decreto-Lei 118/2013) for PM_{10} (50 μg m^{-3}) and $PM_{2.5}$ (25 μg m^{-3}). FC1–FC4 data (distributions and means) of PM_{10} and $PM_{2.5}$ were significantly different ($p < 0.05$) across four fitness centres, and between both occupied and non-occupied periods.

limit set for 24–h (50 μg m^{-3}; Directive, 2008/50/EU), with a median value (15 ± 6 μg m^{-3}) well below the EU annual standard (40 μg m^{-3}). In a comparison, ambient $PM_{2.5}$ levels (1–9 μg m^{-3}) seemed rather low for urban zones, however, Portugal ranks among EU countries with the lowest $PM_{2.5}$ pollution (EEA, 2016); obtained median (4 ± 2 μg m^{-3}) was lower than both EU annual limit (25 μg m^{-3}) and even stricter WHO air quality guidelines (AQG) (10 μg m^{-3}; WHO, 2006). Currently there is no international unique value or guideline approach for PM_{10} or $PM_{2.5}$ concentrations in indoor air (Table 5S) but from the scientific perspective, WHO indoor AQG are probably among the most relevant ones (WHO, 2010). Concerning PM, the WHO leading group experts concluded that current WHO AQG for PM in ambient air (24 h: 50 and 25 μg m^{-3} for PM_{10} and $PM_{2.5}$, respectively; annual: 20 μg m^{-3} for PM_{10}, 10 μg m^{-3} for $PM_{2.5}$; WHO, 2005) are applicable to indoor air (non-industrial settings) in a view of no conclusive evidence of the hazardous nature of PM from indoor sources (when compared with outdoor one; WHO, 2010). The WHO AQG for 24-h also coincide with limits set by the Portuguese norm Decreto-Lei 118/2013, which defines energy certification procedures of public buildings. As such the norm also designates protection limits for selected indoor air pollutants including PM_{10} and $PM_{2.5}$, but the given limits are expressed as 8-h averages (as opposed to 24-h time period considered by WHO (2005)). Considering this legislation, in all FC1–FC4 the means (but also more restrictively the medians) of PM_{10} both during occupied (Fig. 1) periods and for continuous 24-h measurements (Fig. 2S) were below the limit of 50 μg m^{-3}. Regarding to $PM_{2.5}$, the threshold was exceeded at FC1 and FC2 (considering the means) during the occupied periods and 24 h, indicating that the respective occupants (staff and clients) were to some extent exposed to potentially harmful levels of $PM_{2.5}$.

PM_{10} and $PM_{2.5}$ daily profiles of each fitness centre were similar (Fig. 2), which indicates that both PM fractions might originate from the same sources. PM_{10} concentrations were highly (and positively) correlated with $PM_{2.5}$, with Spearman correlation coefficients (r_s) ranging between 0.949 (at FC3) and 0.986 (at FC4). In all four fitness centres, PM daily concentration profiles (Fig. 2) exhibited two peaks: the first maxima appeared around the mid-days (approx. between 10:00–12:00 at FC1; 11:00–13:00 at FC2 and FC3; 11:00–12:00 at FC4); the second maxima were identified during the later afternoon (around 19:00 at FC2 and FC3) or early evening hours (21–22:00 at FC1 and around 21:00 at FC4). These PM concentration maxima corresponded to the busiest periods (in terms of number of exercisers/clients registered in each FC; Table 1). Therefore, it might be assumed that PM levels resulted from the occupant's physical activities (human and equipment emissions, and resuspension of particulate matter due to exercising; Alves et al., 2013, 2014; Ramos et al., 2014; Žitnik et al., 2016). Regarding FC4, it is necessary to point out that the PM_{10} and $PM_{2.5}$ medians were higher ($p < 0.05$) during the vacant periods (22:00–07:00), but the respective concentrations displayed little concentration variations (especially between 00:00–07:00) with somewhat stable profiles. In agreement with the previous findings, in all fitness centres, the maxima of temporal $PM_{2.5}$ and PM_{10} variations registered in the classrooms and studios (group activities) occurred when fitness classes were in sessions (Fig. 3): FC1: 285–459 μg m^{-3} during high-intensity dance class; FC2: 160–213 μg m^{-3} during cycling; FC3: 55–79 μg m^{-3} during cardio muscular class; and FC4: 51–57 μg m^{-3} for cardio class. Finally, $PM_{2.5}$-to-PM_{10} mass concentrations ratios were rather high at all fitness centres with the following medians: 0.94 ± 0.09 (0.46–1.0) at FC1, 0.94 ± 0.09 (0.56–1.0) at FC2, 0.93 ± 0.09 (0.60–1.0) at FC3, and 0.95 ± 0.06 (0.60–1.0) at FC4. These results suggest that PM_{10} was essentially composed of fine particles (with diameters smaller than 2.5 μm) which contributed 95% of the PM_{10}. Apart from the smaller aerodynamic diameter (hence a deeper deposition in the respiratory tract; Feng et al., 2016), $PM_{2.5}$ surface area is larger and it has bigger adsorption ability. Therefore, toxic components (such as heavy metals, carcinogenic compounds, organic pollutants and pathogenic microorganisms) are predominantly bound to $PM_{2.5}$ (Dacunto et al., 2014; Li et al., 2017; Oliveira et al., 2016) and impacts to human health might be greater than of coarse particles (Widziewicz and Loska, 2016). As good indoor air quality is fundamental in indoor spaces such as gyms, where inhalation

Table 2
Summary of existent studies on particulate matter (PM; μg m^{-3}), particle number (PN; # cm^{-3}) in sport facilities.

Year	Country, city	Study description	PM fraction	Levels	Other	Reference
Health club/fitness centres						
2008–2010	Germany (Munich, Stuttgart, Hanau, Regensburg)	4 different indoor climbing centers; Measurements on 1 evening (Thursday) during 7 consecutive weeks;	PM_1 $PM_{2.5}$ PM_{10} PN	PM_1: 5–23 $PM_{2.5}$: 19–160 PM_{10}: 129–1179 PN: 3335–15 070		Weinbruch et al., 2012
2012	Portugal (Lisbon)	11 fitness centres with fitness/ bodybuilding area +2 studios (during classes); Short–term (45–60 min) measurements conducted in the most occupied periods (late afternoon/night); 3 fitness centres with continuous measurements (approx. 6 days); 9 fitness centres with mechanical ventilations;	PM_1 $PM_{2.5}$ PM_{10}	PM_1: 0.9–16 (0.74–18) $PM_{2.5}$: 1.5–23 (0.9–43) PM_{10}: 3.5–101 (1.8–153)		Almeida et al., 2016; Ramos et al., 2014
2012	Portugal (Oporto, Lisbon)	3 sport halls (for gymnastics); Sampling during winter (3 days) and spring (2 days); Measurements taken on the busiest day of the week & during opening hours; approx. 4 h measurements;		Spring: PM_{10}: 716 (250–1270) $PM_{2.5}$: 500 (18–379) Winter: PM_{10}: 658 (77–1200) $PM_{2.5}$: 170 (36–405)		Filipe et al., 2013
n.s.	Greece (Athens)	Personal exposure assessment study of various indoor spaces including 1 gym (unspecified);	PM_4	PM_4: 116–284		Saraga et al., 2014
n.s.	Thailand Nakhon Pathom Province	3 fitness centers: 2 indoor (municipality and university and complexes) and 1 outdoor open-air facility; Field measurements conducted 3 times (beginning, middle and end of operating hours) over period of 39 days;	PM_{10}	PM_{10}: 51–62 (16–163)		Onchang and Panyakapo 2016
Educational facilities						
2005–2009	Czech republic(Prague)	1 elementary school gymnasium; 10 campaigns of 7–12 days long over 5 years; 24 h sampling	$PM_{2.5}$	Cold seasons: $PM_{2.5}$: 25 ± 12.3 (6.3–62.6) Warm seasons: $PM_{2.5}$: 17.6 ± 8.6 (4.5–32.1)		Braniš et al., 2009, 2011
2005–2009	Czech republic(Prague)	3 elementary school gymnasiums; 20 measurement campaigns, each 7 –11 days long; 24 h sampling;	$PM_{10-2.5}$ $PM_{2.5-1.0}$	Weekdays: $PM_{10-2.5}$: 13.6–24.9(1.2–9.2) $PM_{2.5-1.0}$: 3.7–7.4 (0.5–17.5) Weekends: $PM_{10-2.5}$: 1.0–1.8(0.5–4.9) $PM_{2.5-1.0}$: 0.6–1.6 (0.5–5.6)		Braniš and Šafránek, 2011
n.s.	Czech republic (Prague)	Conducted in university sport facilities (Physical Education Department); 3 spaces: 2 conventional gyms, 1 fitness centre; Sampling done during different periods: empty rooms/without ventilation and during normal occupancy (with students/standard ventilation);	PM_1 $PM_{2.5}$ PM_4 PM_{10}	Empty rooms/without ventilation: PM_1: 66–72 $PM_{2.5}$: 72–76 PM_4: 73–78 PM_{10}: 56–80 Occupied/with ventilations: PM_1: 20–22 $PM_{2.5}$: 23–25 PM_4: 25 ± 1 PM_{10}: 29–32		Kic, 2016

(*continued on next page*)

Table 2 (*continued*)

Year	Country, city	Study description	PM fraction	Levels	Other	Reference
2009–2010	Hungary (Debrecen)	3 gymnasiums: 1 preschool, two primary schools; 1-2 week sampling campaigns;	$PM_{2.5}$ PM_{10}	$PM_{2.5}$: 12–15 PM_{10}:70–180	Values retrieved from a graph	Szoboszlai et al., 2011
2011	Slovenia (Ljubljana)	1 university gym hall; 1ne month-long measurements (PM + comfort parameters) during sporting activities;	PM_{10}	Single person's contribution: PM_{10}: increase of 1.5 ± 0.3 (per person per slot); Monthly average PM_{10}: 33		Žitnik et al., 2016
2011	Italy (Cassino)	11 elementary school gyms; Each school monitored for 1 school day; Measurements: 5–10 min before the beginning of the activities in the gyms until the end of the day (approx. 13:30);	$PM_{2.5}$ PM_{10}	$PM_{2.5}$: 17–92 PM_{10}: 33–204		Buonanno et al., 2012a
2012	Spain (Leon)	1 university gymnasium; 1-week measurements Occupied *vs.* background sampling (during weekends); Emphasis on PM distribution during various activities/situations;	PM_1 $PM_{2.5}$ PM_{10} $PM_{>10}$ TSP	With various activities/situations: PM_1: 3–14 $PM_{2.5}$: 6–90 PM_{10}: 13–700 $PM_{>10}$: 2–100 TSP: 13–800 Background (during weekend): PM_1: 2.1 $PM_{2.5}$: 2.7 PM_{10}: 3.2 $PM_{>10}$: n.d. TSP: 3.2		Castro et al., 2015
2012	Spain (Leon)	University facilities: 1 gymnasium and 1 fronton (court to play paddle ball); 1-week consecutive measurements; Weekdays (occupied) *vs.* background sampling (weekends); Emphasis on PM composition;	PM_{10}	Gym: Weekend: 16.8 Weekdays: 177 ± 17.4 Fronton: Weekend: 13.3 Weekdays: 40.0 ± 3.5	Linked with Castro et al., 2015	Alves et al., 2013, 2014
2005/2006–2008/2009	USA Montana	2 schools gymnasiums (middle and elementary school); Before, during, and after woodstove change out; over 4-year period; 24-h samples approximately once per week (during weekday);	$PM_{2.5}$	Winters: $PM_{2.5}$: 21.5–30.5 Non-winters: $PM_{2.5}$: 25.6–52.7		Ward et al., 2013

Note: n.s. – not specified; TSP – total suspended particulate matter; PM>10 – particulate matter with particles larger than 10 μm.

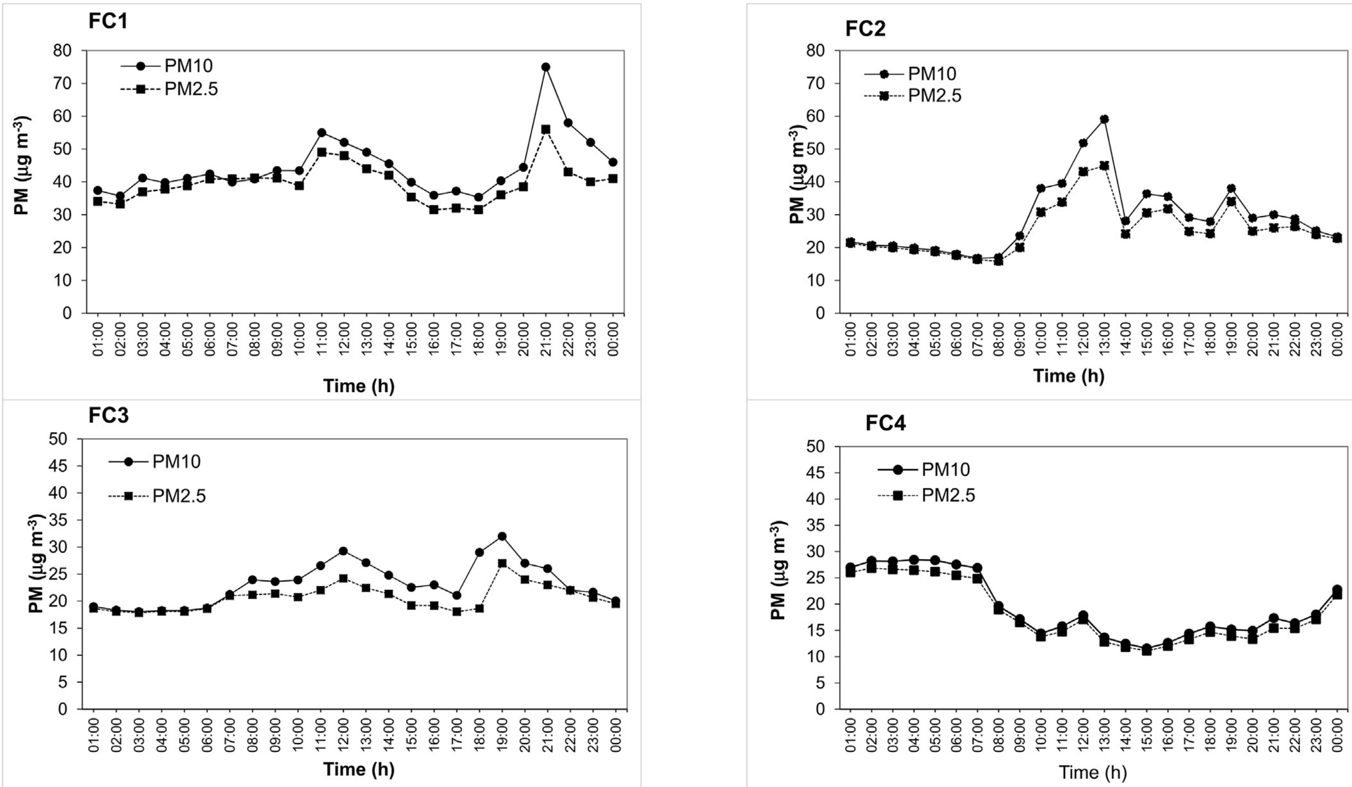

Fig. 2. Mean daily variations of PM_{10} and $PM_{2.5}$ levels at the four fitness centres (FC1–FC4).

intake of PM is elevated (Hodas et al., 2016; Ramos et al., 2015), reasonable measures should be used in order to regulate indoor PM in order to ensure healthy and comfortable indoor environments. Finally, it is necessary to point out that, whereas the medians of mass concentrations ratios were remarkably similar at all fitness centres (0.93–0.95), FC1 and FC2 exhibited (on several occasions) larger contributions (up to 56%) of coarse particles, especially when windows were opened (*i.e.* due to outdoor infiltrations). Some previous studies reported elevated contributions of $PM_{2.5-10}$ in sport facilities especially when using chalk (Castro et al., 2015; Weinbruch et al., 2012); however, that was not the case in the studied fitness centres.

3.2. Ultrafine particles

Number concentrations of UFPs measured at four fitness centres during the occupied and non-occupied periods are presented in Fig. 4 (24-h levels are shown in Fig. 3S). Overall, the distributions of the UFP levels largely varied among the four fitness centres ($p < 0.05$) with the following ranges: 474–88 600 # cm^{-3} at FC4, 2463–46 543 # cm^{-3} at FC1, 916–28 731 # cm^{-3} at FC2, 1004–9 916 # cm^{-3} at FC3. Similarly to PM, the highest overall median of UFPs were obtained in smaller fitness centres (FC1: 9 422# cm^{-3}; FC2: 6 715 # cm^{-3}). In FC with controlled ventilations the obtained medians were approximately 2–3 times lower (FC3: 3 665 # cm^{-3}; FC4: 3 886 # cm^{-3}) than at fitness centres with natural ventilations. These results were in agreement with the literature findings, which showed the significance of outdoor UFP infiltration to indoors. El Orch et al. (2014) estimated that especially particle (aerodynamic diameter $N_{100-1000}$) of outdoor origin are most likely to infiltrate indoors in the greatest numbers (mostly due to the weakest fundamental forces that govern particle removal). The use of mechanical systems (central ventilating, air-conditioning or air cleaners) can then significantly reduce the infiltrations of UFPs indoors (Kearney et al., 2014). Several studies have assessed size-resolved particle filtration efficiencies for filters commonly found in commercial HVAC systems (Azimi et al., 2014; Stephens et al., 2011; Stephens and Siegel, 2013). Specifically, Azimi et al. (2014) reported retention eficiency of outdoor UFPs between ~12 and 13% up to > 98% (depending on the type of filters used). The type of utilized filters is relevant (El Orch et al., 2014), with higher removal efficiencies of UFP being reported for deeper bed filters than for the panel filters (Stephens and Siegel, 2013). However, unlike $PM_{2.5}$, the removal of UFP is reliant to some degree on outdoor particle size distribution and infiltrations factors (El Orch et al., 2014). In addition, air recirculation rates and the fraction of air that is recirculated are relevant for particle removal (Hodas et al., 2016). In the absence of primary source of UFPs (none was idenfied in the studied spaces), UFPs differences among the four fitness centres may be caused by dissimilar comfort conditions (relative humidity, temperature, etc.; Table 1S), by factors related with different building/material characteristics, room occupancies and most likely by the existence of activities or products that may function as potential sources of secondary aerosols (Weschler, 2011). These sources might be especially relevant in FC3–FC4, where due to mechanical systems the infiltrations in ambient UFPs might be largely reduced. Mean concentration of UFP across the four fitness centres was 9 657 ± 10 481 # cm^{-3} for the occupied periods, being approximately twice higher than for non-occupied periods (4 836 ± 2 962 # cm^{-3}). Similarly to PM findings, the highest medians were registered at FC1 (9 718 # cm^{-3} during occupied periods and 8 461 # cm^{-3} when not occupied) and FC2 (7 955 # cm^{-3} *vs.* 4 719 # cm^{-3}), whereas in the large fitness centres the median concentrations were approximately twice lower: 3 738 *vs.* 3 630 # cm^{-3} at FC3, and 5 428 *vs.* 4

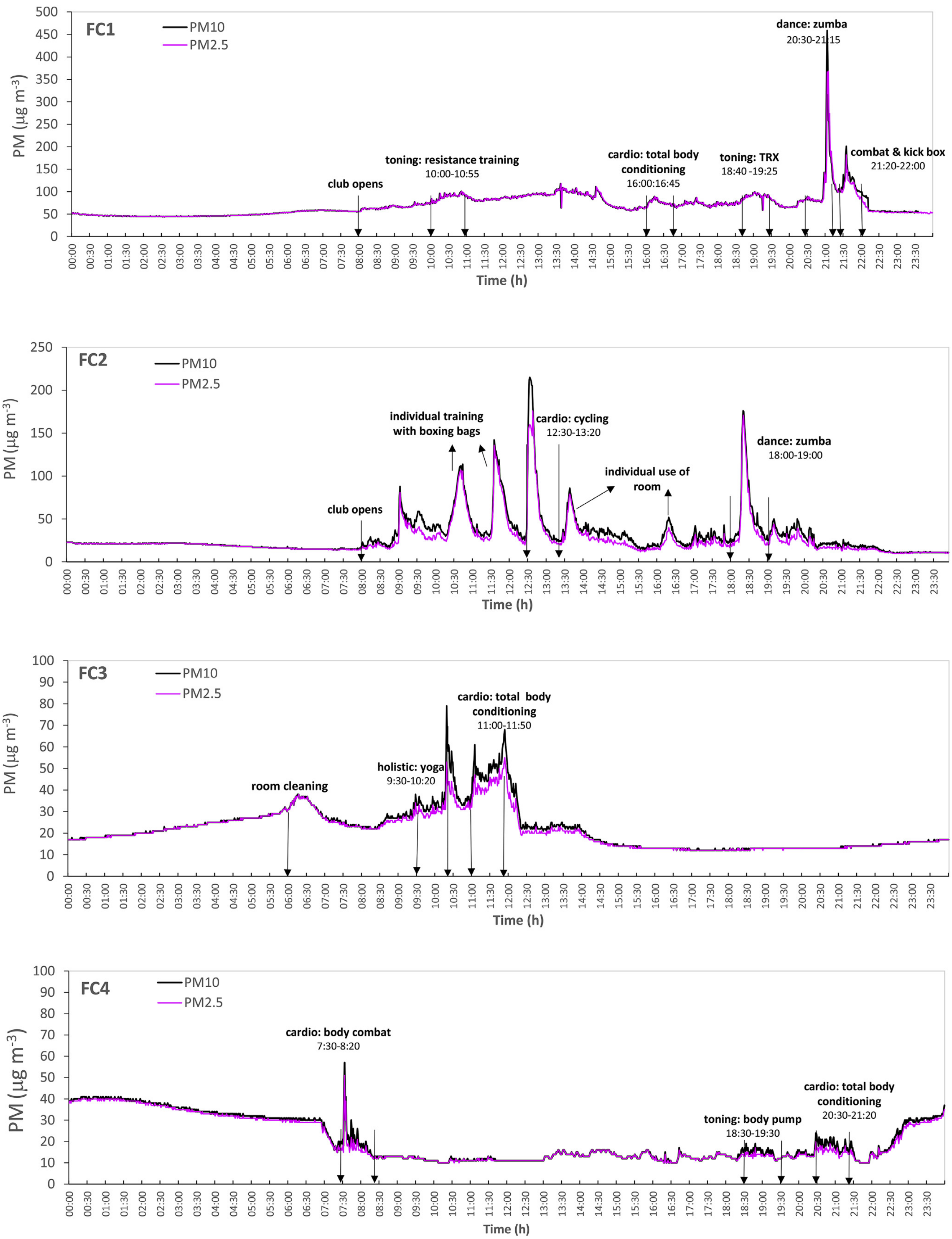

Fig. 3. Temporal variations of PM_{10} and $PM_{2.5}$ in group activity classrooms and studios of the studied fitness centres (FC1–FC4).

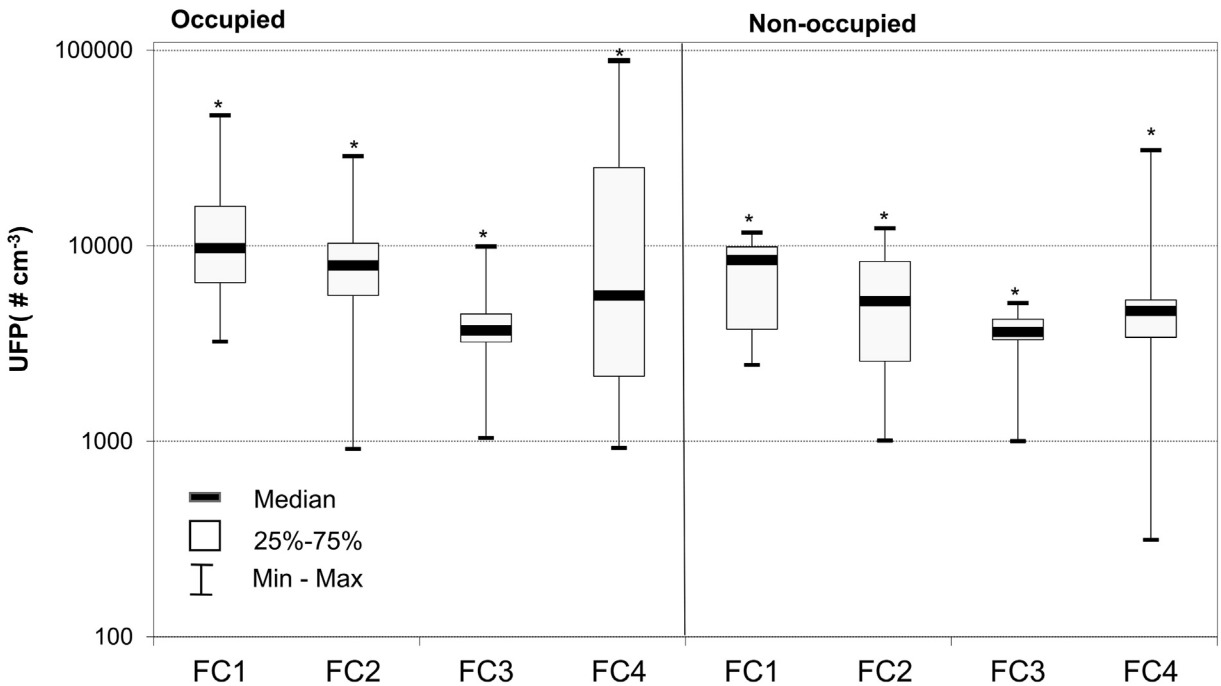

Fig. 4. UFP levels (■ median, □ 25–75%, and ⌶ range) at the four fitness centres (FC1– FC4) during occupied and non–occupied periods. FC1–FC4 distributions of UFPs were significantly different ($p < 0.05$) for both occupied and non-occupied periods. * indicates significantly different ($p < 0.05$) medians between the four fitness centres (FC1–FC4) and across both occupancy periods. Note: for better visualization vertical axis y uses logarithmic scale.

647 # cm^{-3} at FC4. In all fitness centres, median UFP concentrations were significantly higher ($p < 0.05$) during the occupied periods than when not occupied thus indicating the impacts associated with occupancy of the indoor spaces (Kearney et al., 2014; Mazaheri et al., 2014; Reche et al., 2014; Rivas et al., 2014). In agreement, during the occupied periods, the intra-space comparisons (fitness area *vs.* classrooms for groups activities for each centre; Fig. 4S) demonstrated a greater variation of UFPs ranges between the two spaces ($p < 0.05$) than during the vacant periods. At each fitness centres, higher variations of UFP levels were observed in fitness areas. This is understandable considering the greater variability of that microenvironment (in terms of occupants and corresponding emissions, cleaning, regular and unpredicted daily activities, etc.). The mean UFP counts (Table 6S) ranged between 4.6 × 10^{11} (at FC3) and 8.8 × 10^{11} (FC2) # $occupant^{-1}$ for fitness areas whereas it was 2.6 × 10^{10} (at FC4) and 2.5 × 10^{11} (FC1) # $occupant^{-1}$ for the classrooms. It is necessary to highlight that medians of UFPs number concentrations (Fig. 4S) were statically different between the two places of each fitness centre ($p < 0.05$), with the respective concentration levels being at fitness areas 0.9 (FC3)– 1.0 times higher (FC1, FC2) than in group classrooms (Fig. 4S). FC4 was the only place, where median UFP concentration obtained for fitness area was approximately twice higher than in classrooms/studios for group activities (Fig. 4S). On contrary to other sport clubs, fitness area of FC4 was approximately 11 times larger than classroom spaces (opposed to ~2 times difference at FC1–FC3; Table 1).

The information on UFP in indoor spaces has been emerging (Table 7S) but only limited number of the available studies conducted in sport facilities (Table 2) assessed PM distribution and hence reported some findings regarding particle number concentrations. In a series of studies conducted in an university gymnasium (Alves et al., 2014; Castro et al., 2015), authors reported number concentration for fine and coarse mode (N100–10000) of 490–590 # cm^{-3} when exercising (without use of chalk) and 600 ± 160 # cm^{-3} when using chalk. The same studies also noted high elevation of particles during cleaning activities (up to 2400 # cm^{-3}). Weinbruch et al. (2012) observed particle number concentrations (N3.7–10000) in a range of 3300–27 500 # cm^{-3} in indoor air of climbing centres (high activity periods) assuming outdoor origin for the UFP fraction. While all the studies have demonstrated that human activities cause increased particle number concentrations, it is difficult to directly obtained robust comparisons as the studies implied different sampling protocols (dissimilar equipment, continuous *vs.* temporal sampling, different spaces and or physical exercises, etc.), considered different particle fraction (fine and coarse mode *vs.* UFPs) and different seasons (Wheeler et al., 2011).

Overall, UFPs number concentrations showed low-to-moderate associations ($|r_s| < 0.590$) with PM (Table 8S), which can be understood in a view of the different characteristics and behaviour of both particle modes. Fig. 5 shows the mean daily profiles of UFP concentrations at four fitness centres. These profiles were different from those of PM and seemed not to be associated with occupancies of the places. In all fitness centres, since early morning (between 07:00–8:00 depending on the opening hours of each place), UFPs rise and continued to increase with the highest number concentrations recorded around 13–14:00. These increases represented between 50% (FC3) ~ 250% (FC4) when compared with the medians of each space/room. Midday/early afternoon increases of particle number concentrations have been reported in indoor air of classrooms (Reche et al., 2014), being mostly attributed to outdoor nucleation processes events associated with photochemistry (Brines et al., 2015; Wang et al., 2011) and consequent infiltrations indoors. Some authors also reported elevated midday indoor UFPs due to cooking emissions (Fonseca et al., 2014) which seems unlikely for the respective settings. Furthermore, at FC1 (fitness area) maxima UFP were registered later (around 16–17 h). As primary sources of UFP were not identified, it is assumed that UFPs might be generated by formation of secondary aerosols from reactions between ozone and chemicals emitted from cleaning products, furnishings or even occupants themselves (Weschler, 2011). In agreement, Bekö et al. (2015a) reported elevated concentrations of submicron particles in indoor air of aircraft cabins due to ozone-

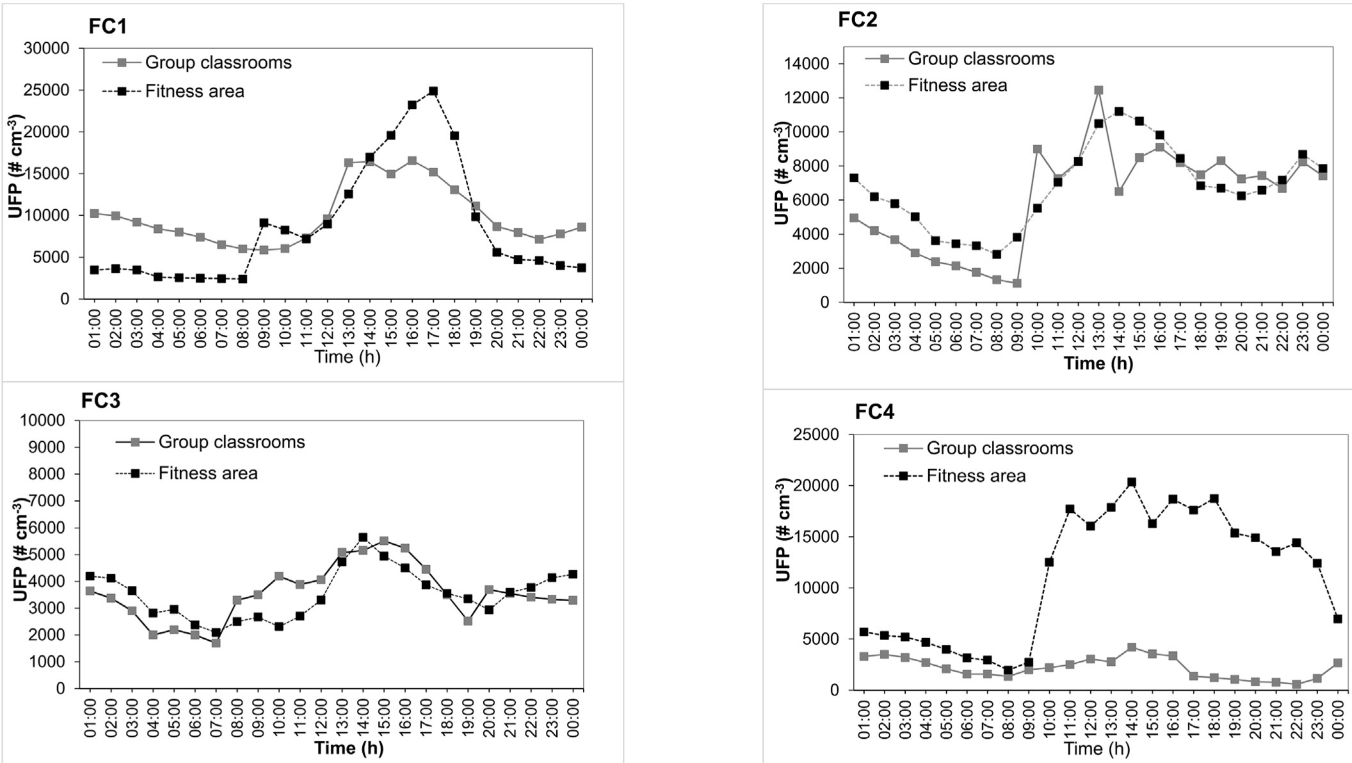

Fig. 5. Mean daily variation of UFPs in four fitness centres (FC1–FC4). The continuous line represents mean concentrations based on the measurements in classrooms (group activities), whereas dash lines represent mean levels obtained in fitness areas.

initiated reactions. Higher levels of ozone in ambient air (>100 μg m^{-3}) and low indoor relative humidity (below 50%) can also generate indoor nucleation events (Hovorka and Braniš, 2011). In two out of four fitness centres (FC2, FC3), median RH was lower than 50% (Table 1S). Correlation coeficient between UFPs, temperature (T) and relative humidity (RH) were significant across the four fitness centres, but in general demonstrated low strength of associations ($|r_s|$<0.426; Table 8S). At all fitness centres, UFPs concentrations were positively correlated with T, whereas for RH the directions of associations varied. At FC1 and FC3, UFPs were inversely correlated with RH, at FC2 and FC4 the observed associations were positive. These obtained differences could be caused by different particle distributions at the respective centres. While UFPs are dependent both on T and RH, the effect of T was reported as dominant mainly for the lower particle size ranges (N1–50) whereas RH mostly influences the larger particle size ranges (N50–880) (Jamriska et al., 2008).

3.3. Inhalation dose assessment

The inhalation dose of UFPs estimated for female and male subjects performing different physical activities at four fitness centres are presented in Fig. 6. In general, UFPs doses were the highest for groups (both genders, all age categories) at FC1 (1.2 times in comparisons with FC2 and 1.6–2.6 times for FC3–FC4), most likely due to higher overall UFPs levels registered in indoor spaces of the respective gym. Both males and females exhibited the highest doses during high intensity cardio group activities, being approximately 2 times higher than for holistic classes. Obviously, the elevated breathing rates during the cardio exercises caused the increased intakes. Across the three age categories of females, the cardio/holistic ratio of inhaled UFPs doses ranged between 1.92 and 2.00, whereas for exercising male subjects it was 1.79–1.85. For fitness training, the obtained ratios (cardio/fitness) were lower (1.21–1.44 for females; 1.18–1.38 for males). Firstly, the fitness training typically lasts longer (under this scenario we assumed 1 h, i.e. extra 20% of time). Secondly, it usually includes both high–inhalation rate cardio activities (warm-up at beginning of exercise; 20 min) and moderate-inhalation individual training (free weights, machines, equipment, etc.; 40 min). Finally, the comparisons between both genders showed that on average UFP doses of women were 1.2 times higher than of men, with the highest differences obtained for cardio classes (15–22% for 31 to <41 and 41 to <51 yrs old). These findings were in accordance with previous study of Ramos et al. (2015) who reported gender-specific inhalation doses for exercising population (20 subjects); the overall intake was 1.5 time higher for women, possibly due to larger limitation of expiratory flow in female subjects and increased efforts to breath when conducting intense physical activities (Ramos et al., 2015). It is necessary to highlight that estimated UFP doses are influenced by both gender-specific factors (i.e. body weight and inhalation rate), both being also depend on the age of a subject (USEPA, 2011). These parameters were not directly measured in the respective population but retrieved from USEPA (USEPA, 2011), with inhalation rates showing slightly higher variability between different age group (IR female: 93–97%, male: 92–96%) rather than body weight (95–96% for male and 94–97% for female). In addition, USEPA recommended values for BW of the respective female group ages seemed rather high (79–85 kg) for Portuguese population. Thus BW (61 kg) reported directly for Portuguese women (23–38 yrs old) were used (Ramos et al., 2015). The same study also reported BW for male Portuguese population, but this value could not use because of the large age difference between the considered subjects (18–29 yrs *vs.* 21–51 yrs in this study). Therefore, the potentially higher BW that were considered for male populations might lead to underestimation of UFP does exposure (in

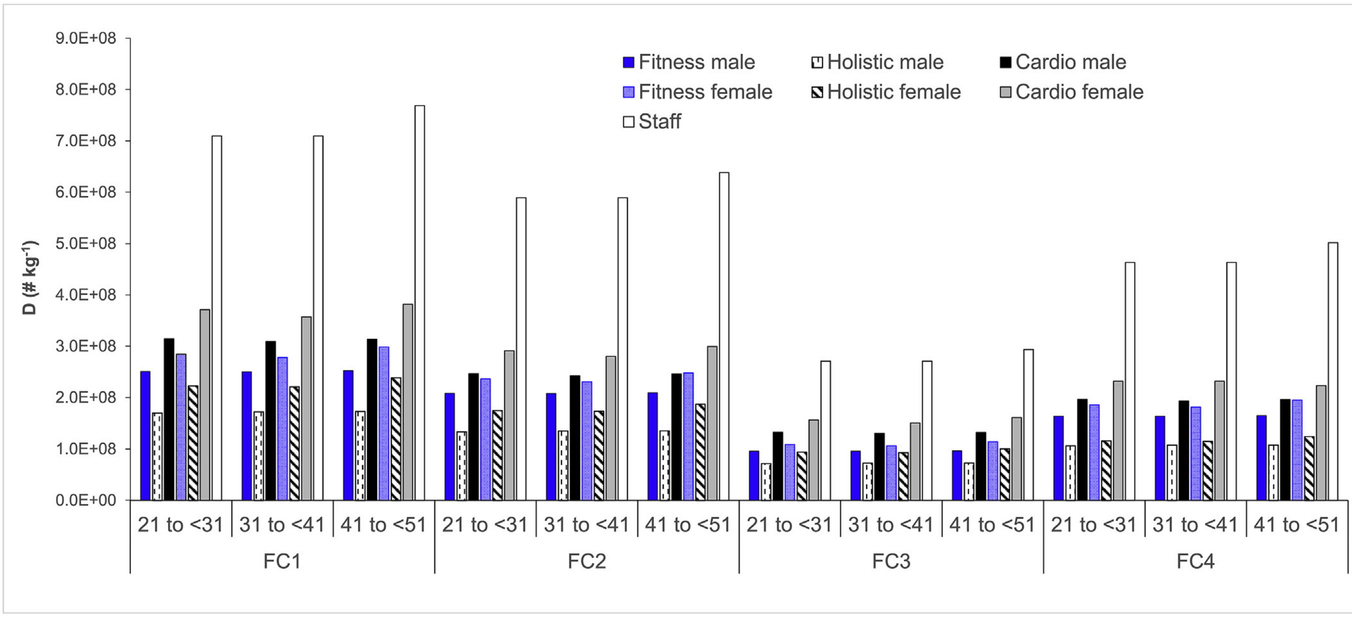

Fig. 6. Estimated inhaled dose of UFP for female and male exercising subjects and staff during various physical exercises.

comparisons with females) and the obtained results need to be implicated carefully.

For comparison, the inhalation intake of UFPs was also estimated for staff and instructors (male and female combined) who monitor the fitness area. UFPs intake due to 8-h occupational exposure was 2–5 times higher than for exercising subjects. It is necessary to remark that daily inhalation intake of pollutants will be influenced by exposures in other non-occupational micro-environments. Despite emerging number of works focused on UFPs assessment (such as for child-relevant environments; Buonanno et al., 2012b; Fonseca et al., 2014; Mazaheri et al., 2014; Reche et al., 2014) lesser knowledge is available regarding UFPs exposures in public spaces (Bekö et al., 2015a, 2015b) or homes (Bekö et al., 2013). Therefore, UFPs in these environments should be further characterized in order to correctly assess the overall daily dose. This is even more relevant for people who frequent fitness centres for health/recreational purposes and thus spent only limited amount of time in this indoor environment on a daily basis.

4. Conclusions

In the nowadays society, for which sedentary routines have become a common standard, it is important, more than ever, to promote healthy lifestyle, one that should include some degree of physical activity. There are countless benefits of exercising being continuously highlighted by international organizations. As a response, people make the efforts of exercising in fitness centres, gyms or even outside. Yet the conditions of the places are relevant, polluted air of these environments can counter the positive effects of exercising to human health. Thus this work assessed particulate pollution in indoor air of fitness centres. Across the four fitness centres the indoor air quality varied with both PM and UFPs showing large temporal and spatial variations. Overall, PM_{10} levels were below the limit value of 50 μg m^{-3} defined by Portuguese legislation at all fitness centres (Decreto-Lei 118/2013). Regarding $PM_{2.5}$, median concentrations exceeded at FC1 and FC2 thresholds of 20 μg m^{-3}, indicating potential risks for the respective occupants. PM_{10} was mostly composed of fine particles (median 0.93–0.94) with both PM fractions highly and positively correlated (r_s 0.949–0.986) thus suggesting the similar origin. During the occupied periods, PM levels were higher ($p < 0.05$) than for vacant periods, temporarily increasing up to 2–16 times (when compared with median of the rooms). PM maxima of daily concentrations coincided with the busiest hours of fitness gyms (in terms of occupancy) indicating that indoor levels were influenced by the intense physical exercising activities. Concerning UFPs, lower (2–3 times) median were obtained at fitness centres with controlled ventilation systems. In all fitness centres, UFPs levels were significantly higher ($p < 0.05$) during the occupied periods with larger temporal variations of UFPs levels in fitness areas. Sources of primary UFPs were not identified in none of the studied spaces. Apart from ventilation systems, UFPs differences among the four fitness centres might be associated with different activities or existence of products enabling formation of secondary aerosols. To further confirm this finding an association between UFP and other gaseous pollutants should be considered. Finally, correlation coefficients between UFPs, temperature and relative humidity were significant across the four fitness centres, but in general demonstrated low strength and different orientations, possibly due to different particle size distributions. Therefore, analysing the particle size distributions in indoor air of the respective fitness centres would be important.

Cardio activities (group classes) led up to twice higher UFPs intakes than other types of exercising. These results indicate that even short-term physical activity (or more specifically its intensity) might strongly influence the daily inhalation dose. However, UFPs inhalation intakes of exercising might be somewhat under/over-estimated, especially mainly for the individuals training in fitness areas due to the large variety of parameters considered (exercise duration, type and intensity of workout plan, physical conditions of subjects). In addition, the inhalation doses in this work were assessed using median UFPs concentrations of each space whereas the large temporal variations in the UFPs concentrations was observed, especially within the fitness areas. Finally, women exhibited 1.2 times higher UFPs inhalation than men thus emphasizing the need of gender-specification in future exposure assessment studies (Ramos et al., 2015). Finally, it is necessary to point out that the present study was conducted during limited period (40 days) during only warm season. Therefore, in future work variation of indoor air pollution and the impacts of seasonal trends should be considered, which will be particularly relevant for exposure assessment in places with natural ventilation. Concurrent measurements of indoor and outdoor UFPs levels should be conducted in order to better improve the source analysis and identify the predominant source of UFPs (outdoor infiltrations *vs.* indoor activities) in the respective places.

Acknowledgments

This work was supported by European Union (FEDER funds through COMPETE) and National Funds (*Fundação para a Ciência e Tecnologia*) through projects UID/QUI/50006/2013 and UID/EQU/00511/2013-LEPABE, by the FCT/MEC with national funds and co-funded by FEDER in the scope of the P2020 Partnership Agreement. Additional financial support was provided by *Fundação para Ciência e Tecnologia* through fellowship SFRH/BPD/65722/2009.

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