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Exploring the impact of commercial wearable activity trackers on body awareness and body representations: A mixed-methods study on self-tracking

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ABSTRACT

Wearable trackers are believed to enhance users' self-knowledge, but their impact on the relationship that people have with their own bodies is relatively unexplored. This study aims to shed light on the potential of physiological data collected by a commercial wearable activity tracker to influence how users relate with their own bodies, specifically their body awareness, body image, body consciousness, and body surveillance. Additionally, the study seeks to determine whether this change in body perception improves or worsens the users' relation with their own bodies. We recruited 321 first-time wearable users, including a control group. Participants in the experimental group (N = 225) completed a set of scales and questionnaires addressing body awareness and representations before and after wearing a Fitbit for four months, and 20 of them were further interviewed about their experience. The findings indicate that participants' overall view of their bodies was not influenced by the device. However, the Fitbit did increase the awareness of bodily sensations, particularly for women. Moreover, we describe how participants made sense of the data displayed by the Fitbit, which was also used as an emotion-regulation tool. These results can contribute to the understanding of the impact of self-tracking technologies on the users' perceptions of their own body and provide insights for future research in this field.

1. Introduction

The growing availability of wearable devices has boosted the popularity of self-tracking technologies, which aim to support users in obtaining better self-knowledge and self-awareness (Wolf, 2009), by facilitating the automatic collection of personal data (Bode & Kristensen, 2015; Rapp & Tirassa, 2017; van Dijk et al., 2015). As the worldwide shipment of wearables reached around 171 million products during 2021 (Laricchia, 2023), self-tracking has become popular among the general public, widening the possibilities of its adoption and integration in daily life (Rapp & Cena, 2016). An increasing number of people are now leveraging these tools to "quantify" a variety of aspects of their everydayness, like health, sports, habits, and psychological states (Li et al., 2010; Rapp et al., 2018).

Among self-tracking technologies, wearables are of a special kind: they are body-worn computational, sensory, and interactive devices which enable the automatic collection of body and activity data (Rapp, 2023); frequently, they connect to a mobile app offering supplementary features for data analysis and visualization (Day, 2016; Goodyear et al., 2017; Kerner et al., 2019); and they can provide continuous feedback on the user's physiological states, potentially connecting her more in-depth to her body processes (Rapp, 2023).

The body's relationship with wearables can be studied in terms of some key constructs that can be divided in two categories. First, *body consciousness*, namely, the individual's interest in both the private (e.g., sensations) and the social (e.g., appearance) aspects of the body, and *body awareness*, namely, the individual's attentional focus on the "internal aspects" of the body; second, *body image* and *body surveillance*, constructs that refer to the way users represent their own bodies. These are relevant indicators of how we relate with our bodies (e.g., Ainley & Tsakiris, 2013; Baker & Wertheim, 2003; Mehling et al., 2009).

Indeed, literature suggests that wearable devices can shape how

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users perceive their bodies (Rapp, 2023), acting as "mediators" to enhance haptic sensations (Delazio et al., 2018) and perceptual experiences (Gibb et al., 2015). Wearables can foster self-awareness (e.g., Chianella et al., 2021), well-being (Roquet & Sas, 2020; Shusterman, 2012; Ståhl, Tsaknaki, & Balaam, 2021), and assist in managing bodily symptoms, like those engendered by the menstrual cycle (Søndergaard et al., 2021; Woytuk et al., 2020), menopause (Bardzell et al., 2019), or chronic illnesses (e.g., Lupton, 2019; Mishra et al., 2019; Schroeder et al., 2018), as well as enhance physical performance (e.g., Rapp & Tirabeni, 2018, 2020).

However, such technologies are not without flaws (Ledger & McCaffrey, 2014; Michaelis et al., 2016): wearables often offer a reductionist, abstract, and fragmented view of the body, being based exclusively on numbers, graphs, and statistical depictions (Boldi & Rapp, 2022; van Dijk et al., 2015), potentially causing disembodiment and dissatisfaction (Lupton, 2016a). Such numerical emphasis can obscure self-understanding (Rapp & Boldi, 2023; Rapp & Tirassa, 2017) and even result in device abandonment if people do not find sense in the data collected (Lazar et al., 2015; Rapp & Cena, 2016). In this sense, wearable trackers might even encourage self-surveillance practices, namely, excessive monitoring of the body, and decrease satisfaction with one's body image (Goodyear et al., 2017).

While studies have reported both benefits and detrimental effects following from the usage of wearables (e.g., Fritz et al., 2014; Rapp & Tirabeni, 2020; Rooksby et al., 2014), their overall impact on body perception remains substantially underexplored. In particular, there is no clear understanding of whether and how popular commercial wearable activity trackers may affect user body representations and awareness. This is crucial since increasing self-awareness, a primary objective of these devices, relies on understanding and influencing body perception, as knowledge is always situated and embodied (Ihde, 2009). Moreover, commercial wearable devices are now so popular that it has become paramount to understand whether they can really affect how people relate to their own bodies.

In this article, we aim to contribute to self-tracking research in a twofold way. First, we aim to understand whether and how commercial wearable trackers affect users' relationship with their own bodies: although these devices ostensibly enhance bodily awareness, limited empirical research analyzes such an effect on different interrelated body constructs. Given the scarcity of unambiguous results in previous literature, we wanted to conduct an exploration to gain a broad understanding of the phenomenon with an open-ended research question:

RQ1. Do commercial wearable trackers have any kind of effect on user body awareness and body representations?

Second, we aim to determine whether this change is beneficial, namely, whether users feel that the relationship with their own bodies improves following the usage of wearables (e.g., they gained an improved body image), with possibly positive consequences on their life, or rather find it detrimental. Not enough research has provided directional pointers to this issue, highlighting both positive and negative effects of using trackers (e.g., Esmonde, 2019; Rapp & Tirabeni, 2018). We then decided to maintain the exploratory nature of our investigation by raising the following research question:

RQ2. Do commercial wearable trackers improve or worsen the users' relation with their own bodies?

To do so, similar to Busch et al. (2020), we focus on first-time users as we expect that a potential change in the user's relationship with her body due to the use of wearables would be more evident and easier to detect if she is not already accustomed to using such technology. Moreover, we aimed to avoid biases from involving experienced individuals who may use wearables for specific bodily purposes and may have peculiar ways to relate to their own bodies (like athletes, as suggested by Rapp & Tirabeni, 2018; Rapp & Tirabeni, 2020). Instead, our focus was the broader general population's experience with these technologies.

To answer these research questions, we carried out a mixed-methods study. A large sample of participants (N = 321), including a control group, was involved in a quantitative study. The experimental group used a Fitbit device for a 4-month period, and participants were assessed using various body-related questionnaires both pre- and post-experience. Additionally, we conducted a qualitative study involving semi-structured interviews with a sub-sample of 20 individuals from the experimental group.

The remainder of the paper is structured as follows. First (Section 2), we provide an overview of the theoretical framework that serves as a basis for this work, and of the previous studies conducted on self-tracking technologies and the body. Then, we describe the methodology (Section 3) followed in our research and present the results (Section 4). We then discuss them with respect to similar studies in Section 5. We provide some suggestions for designing self-tracking devices in Section 6, then outline the limitations of our study and conclude the paper respectively in Sections 7 and 8.

2. Background

2.1. The centrality of the body

The body is central in shaping the individual experience of the world. Scholars use the term *embodiment* (Besmer, 2015; Ihde, 1990) to claim that our pragmatic possibilities to interact with the environment are anchored to our body and to its somatosensory capacities (Berthoz, 2017; Gallagher, 2005). The body deeply affects and "mediates" the experience of ourselves, of others, and the world in general (Gallagher & Zahavi, 2007). In other terms, as studies in neuroscience would argue, the internal models of the body that humans have in their brain allow people to have a dialog with reality (Berthoz, 2017).

The relationship with our bodies, however, is mediated as well. Human body perception is a complex process which is influenced by cognitive, emotional, and even cultural factors. Psychologists have developed several theoretical constructs that attempt to operationalize the way people stay in connection with their own bodies, such as *body consciousness*, *body awareness*, and *body image*. Miller et al. (1981) used the expression "body consciousness" to refer to the individual's interest in both the private, that is, the internal sensations, and the social aspects of the body, namely the awareness of its appearance (Miller et al., 1981). "Body awareness", which is also referred to as "interoceptive awareness" (IA) (Mehling et al., 2012), is the "internal aspect" of body-consciousness and is central for building the sense of the bodily self (Ainley et al., 2013). This construct broadly refers to the attentional focus on the flow of information about the body that is continuously available to our senses (De Vignemont, 2020). Body image, instead, is a more complex construct encompassing thoughts, feelings, and behaviors related to the body (Bailey et al., 2017). Finally, the construct of *body surveillance*, which indicates the monitoring and surveillance attitudes of individuals towards their own body (McKinley & Hyde, 1996), offers insights into how people perceive it "from the outside". This practice can manifest itself in terms of body checking behaviors, that entail the repeated checking of body parts or weight, serving as an attempt to gauge body size or shape (see, e.g., Reas et al., 2002; Shafran et al., 2007). In this sense, body checking may be a proxy to body surveillance, given the active monitoring and scrutiny involved.

Drawing from this knowledge, some scholars argued that technology has the potential to transform our possibilities to experience our own corporeality (Secomandi, 2018; de Boer, 2020). In this sense, self-tracking instruments enabling the continuous collection of body data are believed to change our capability of sensing the body and to increase people's awareness of their own body processes (Kristensen & Prigge, 2017). However, there is still relatively scarce empirical research investigating how technology affects the experience of corporeality (Secomandi, 2018), especially concerning wearables and body psychological constructs. For instance, a randomized controlled study was conducted to analyze the impact of self-tracking via fitness apps on novices, but it found no improvement in their trust in body sensations or ability to listen to their bodies after 6 weeks (Busch et al., 2020).

The remainder of this section outlines a series of studies addressing how self-tracking technologies could mediate user body representations, by focusing on the body-related constructs introduced above.

2.2. Awareness and self-tracking

Literature on trackers has focused more on the construct of body awareness, showing that augmenting the perception of body stimuli through the visualization of body parameters (i.e., biofeedback) could increase the awareness of the body (van Dijk et al., 2015), improve psychological well-being (Brani et al., 2014) and even treat generalized anxiety (Rice et al., 1993). In this line of research, it is believed that wearable devices can help people acquire a more "watchful mind", being more aware of sensations that are considered barely perceivable (Sharon & Zandbergen, 2016).

Some qualitative studies appear to support this. Runners interviewed by Esmonde (2019) declared that the feedback provided by wearable trackers helped them become sensitive to their body. Similar claims were made by participants in other studies, who wore self-tracking devices and reported being more aware of their bodily reactions (Ruckenstein, 2014) or that they could better recognize the triggers of their health symptoms (Choe et al., 2014). In this vein, Suh et al. (2016) described how different perceptual properties of wearable devices (e.g., materials, vibration, weight) may influence user body awareness. However, this optimistic view on the positive effect of wearables on body awareness was challenged by Busch et al. (2020). These authors conducted a 6-week long controlled experimental study with the Fitbit, providing participants with the goal to reach 10,000 steps per day. They found that neither body trusting nor body listening (which are sub-dimensions of body awareness) changed after the end of the experiment.

While improving one's body awareness might sound like an appealing goal for individuals, scholars also raised concerns that excessive scrutiny of physical sensations may even be detrimental. Rapp and Tirabeni (2018, 2020), in the sports domain, highlighted that an excessive reliance on body data collected by wearables may reduce rather than improve body awareness. Paying more attention to body states may even be linked to emotional distress and maladaptive eating behaviors (Ainley & Tsakiris, 2013), as well as worsen stress symptoms and anxiety, increasing preoccupation with one's health (van Dijk et al., 2015). In sum, there is still no clear understanding whether wearable devices can really affect a user's body awareness and in what direction (i.e., beneficial or detrimental).

2.3. Body surveillance and self-tracking

Sociology researchers (e.g., Berry et al., 2021; Lupton, 2014; Goodyear et al., 2017; Ruckenstein & Schüll, 2017) have claimed that constant observational procedures performed by self-trackers would encourage the objectification of the body. Thinking about the body in its quantifiable terms would yield excessive emphasis on data, while obscuring the fleshy and corporeal experience we have of ourselves (Toner, 2018). Franzoi (1995) refers to the notion of "body objectification" to explain how self-tracking would encourage a conception of the body as composed of discrete parts, rather than as a dynamic process.

In psychology, the objectification of the body has also been studied with regard to young women in Western societies: the objectification of women's bodies implies that these are treated as "objects", whose ideal appearance is culturally and socially determined (Liss & Erchull, 2015). According to McKinley and Hyde (1996) a common manifestation of body objectification is that of "body surveillance", a psychological construct that refers to the monitoring and surveillance attitudes of individuals towards their own body. It is then reasonable to hypothesize that using digital trackers, which continuously prompt data about one's own body, may exacerbate a tendency to perceive the body as an "object", namely, something that is seen from a third-person perspective, thus inducing surveillance practices. That said, there is a scarcity of studies conducted from a psychological perspective and that empirically investigate to what extent the use of trackers may, if so, push users to be overly attentive to the appearance of their body.

Empirical research on this matter generally revolves around the sociological and philosophical concept of "biopower" (Foucault, 1990), a form of subtle influence exerted by technology on the user's body. As clarified by Reiby et al. (2022), biometric surveillance may occur since wearables embed values and performance standards (e.g., how many steps to walk) that users are pushed to comply with. Research has shown that users are susceptible and tend to trust the data (Ruckenstein, 2014) and internalize fitness standards (Goodyear et al., 2017), but not everyone seems to be subjected to the "power" of technology. For instance, Goodyear et al. (2017) qualitatively investigated the experiences of 100 young teens who wore a Fitbit for an eight-week period at school, finding that some students resisted surveillance by manipulating the step count and not wearing the device. Similarly, Lupton and Maslen (2019) found that some users may have a more critical approach towards the prescriptive insights offered by wearable trackers.

2.4. Body image and self-tracking

Even though a univocal definition is difficult to achieve, body image points to a conceptual and cognitive representation of the body. Being a subjective representation, body image should not be conceived as an exact copy of the body as it appears from the outside (Bode & Kristensen, 2015), rather it points to the evaluations that we make of our bodies and the emotions associated with those evaluations (Gallagher, 2005). In other words, this construct is related to the narrative aspect of the self or the "stories" that we tell about ourselves (Sabik et al., 2018). The complexity of the body image construct is apparent if we consider that more than 150 measures have been developed in the attempt to assess how people represent their own bodies (Kling et al., 2019). This variety might depend on the multidimensionality of the construct, which encompasses beliefs, thoughts, emotions, attitudes, and cultural values connected to the body (Bailey et al., 2017).

Some studies have been conducted to explore whether self-tracking technologies and, in particular, wearable ones, do really impact body image. A positive effect was shown by Kerner et al. (2019), who found that a group of adolescents experienced a decrease in body dissatisfaction, measured with the BMI-based Silhouette Matching Test, after wearing a Fitbit for a period of five weeks. Likewise, Gittus et al., (2020) noticed that individuals who were requested to wear a Fitbit for a 10-day period were less likely to engage in maladaptive behaviors (e.g., binge eating, dietary restraints) with respect to people in the control group. However, data collection was limited to a short period and researchers could not exclude that detrimental effects could emerge from prolonged use of the device.

As a matter of fact, literature has also pinpointed the relationship between a negative body image and constant monitoring. Dissatisfaction with body image may be a reason why people engage in body monitoring, as found by Edwards (2017), but it could also be an unwanted outcome. In fact, self-tracking tools may provoke or worsen already existing psychological disorders related to body image: for instance, the extreme focus on numbers and calorie visualization may negatively impact users who are struggling with poor body image (Eikey & Reddy, 2017). Similarly, prolonged use and punishing notifications may exacerbate and elicit maladaptive body-related attitudes (Honary et al., 2019).

2.5. Body and self-tracking: research gaps

By and large, research on the quantification of the body operated by technology and its subsequent dematerialization in a variety of data leads to contrasting results: technology seems to have double-edged or no effects on individuals' body perception and understanding, which points to the need for a deeper exploration of the relationship between wearable trackers and the user's body.

Despite the valuable contribution brought by some research, most previous studies did not explicitly explore how technology could mediate the users' rapport with their own body. These studies generally described the practice of personal tracking (e.g., Choe et al., 2014; Rooksby et al., 2014) and how data are interpreted by users (e.g., Coşkun & Karahanoğlu, 2022; Mentis et al., 2017; Rapp, 2018), or they studied the effectiveness of such technologies in motivating healthy behaviors (e.g., Fritz et al., 2014). Even though self-tracking is allegedly believed to increase the awareness of our "selves" and bodily states (Rapp & Tirassa, 2017), there are few empirical studies that specifically and thoroughly examine the interaction between body awareness and wearable technologies among the general population, which is increasingly adopting wearable trackers. The same can be argued for research on body image and self-tracking, which has been mostly studied from the perspective of eating disorders (e.g., Berry et al., 2021; Gittus et al., 2020). Instead, we are interested in exploring the topic in a non-clinical population since current activity trackers are mostly designed for and distributed to the wider public. Furthermore, studies on wearable technology and body surveillance adopt a sociological perspective, regardless of the psychological aspects of self-observation.

It remains to be said that most psychological studies on self-tracking and body investigate a single psychological construct separately from others. However, the boundaries between these bodily representations are far from clear. Body image and body awareness are intimately related (Pylvänäinen & Lappalainen, 2018). Reduced body awareness may be linked to a more negative body image (Badoud & Tsakiris, 2017) and certain dimensions of body awareness appear to be profoundly connected to the way people represent their own bodies, that is, they place their confidence in their own bodies and regard interceptive signals as "safe" (Todd et al., 2019). Moreover, an excessive focus on the body could lead to an objectified vision of the body and the enactment of surveillance behaviors (Ainley & Tsakiris, 2013). Given these interconnections, a more sensible approach is to investigate how all these representations operate in a single individual and may be affected by the usage of technology.

To the best of our knowledge, there are no empirical mixed-methods studies that have been conducted with the specific aim to study how both body awareness and body representations are shaped by wearable devices. Moreover, most controlled empirical studies are conducted for a limited period of time (e.g., Gittus et al., 2020; Kerner et al., 2019) which could bias the results due to the influence of a "novelty effect", while we investigated psychological dynamics across a 4-month period.

Table 1 presents a summary of related works, providing definitions of the key body constructs presented, the research gaps identified in the literature and how these connect to the main research questions.

3. Materials and methods

We wanted to detect if any changes would occur in the participants' perceptions of their own body after using a self-tracking wearable device for four months. To do this, a mixed-methods study was conducted. We employed quantitative instruments (*questionnaires* and *scales*) to determine the direction of change, and qualitative instruments (*semi-structured interviews*) to provide explanations for any changing and non-changing dynamics that were reported by the participants. In this section, we describe in detail the design of our study and the measures performed. In addition, we provide further details on the methods and the material used in this study through a dedicated Open Science Framework (OSF) repository.[1] The study was approved by the IRB of our institution.

3.1. Sampling procedure

The sampling procedure is presented in Fig. 1. The participants were undergraduate and graduate students recruited from two research institutes located in Lausanne, Switzerland, namely the University of Lausanne and the EFPL (École Polytechnique Fédérale de Lausanne). We obtained the support of a specialized unit at the University of Lausanne, called LABEX, to manage the pool of participants, which counts around 8000 students, to take care of the enrollment processes, transfer the financial incentives, and protect participant contact information. The participants were contacted by e-mail and, if they showed interest in the study, they were asked to fill out a questionnaire which was aimed at verifying their eligibility.

A total of 981 individuals answered the questionnaire, of which 429 fit the inclusion criteria, which were: (1) be 18 years of age or older; (2) master the local language; (3) own a smartphone that is compatible with the provided device, namely, a Fitbit; and (4) have never owned or used a fitness tracker. We finally enrolled 225 individuals, according to the number of withdrawals during the data collection campaign and the devices we had at our disposal. A control group, composed of 96 individuals, was also recruited. The sizes of both groups primarily reflected practical and budgetary constraints. Nevertheless, a post-hoc power analysis supported the adequacy of the sample size of the experimental group in detecting the observed effect (see Section 4.2.3 for details). We also considered the smaller size of the control group appropriate, due to its role as a comparative benchmark and the more consistent experience among its members, who were not exposed to the same variables as the experimental group (e.g., possible dropouts, device malfunctions).

For the second phase of the study, we followed Marshall's (1996) principles of sampling in qualitative research, adopting an iterative, inductive, and flexible sampling process to recruit and interview a sub-sample of the experimental group. Since we wanted to provide an in-depth understanding of changing and non-changing dynamics triggered by the use of wearables, we actively looked for "rich informants" (Patton, 1990), who could provide a clearer depiction of the phenomenon. From a list of 122 participants who had initially expressed their willingness to be interviewed in the second phase of the study, we looked for participants who made use of the Fitbit and showed a great change, mild change or no change in the variables measured by the questionnaires. To increase the representativeness, we balanced the group in terms of gender. After having identified a list of potential participants, we contacted them by e-mail and by phone to verify their availability. On that occasion, we asked briefly about their experience and explained the purpose of the interview. The final sample included 20 participants.

3.2. Participant characteristics

The final sample (experimental and control groups) of participants (N = 321) in the first phase of the study included 198 women (61.7%), 120 men (37.4%) and 3 subjects who did not identify with a binary gender (0.9%), below identified as "other". There were 96 participants in the control group, of which 56 are women (58.3%), 38 are men (39.6%), and 2 are other (2.1%). There were 225 participants in the experimental group, of which 142 are women (63.1%), 82 are men (36.4%), and 1 is other (0.4%). The average age is 21.8 (SD = 2.81) and stable between groups. All the participants were students. See Table 2.

The sub-group of participants who took part in the second phase of the study (N = 20) was composed of 10 women and 10 men (see Table 2

[1] Link to our OSF repository: https://doi.org/10.17605/OSF.IO/Q5FK3

Table 1
Summary of related works and link to research questions.

Body Construct	Definition/Key Components	Literature Discussions	Research Gaps	Link to research questions
Body Awareness	Internal focus on body sensations; Intimately linked with sense of self	● Studies have explored whether the visualization of body parameters (i.e., biofeedback) could increase the awareness of the body and improve well-being ● Other research has investigated whether paying more attention to body states using wearables may reduce body awareness or be linked to emotional distress and maladaptive behaviors	● It is not clear whether and how wearables impact individuals' body awareness ● There are few empirical studies on wearables and body awareness and consciousness among the general population ● Most research is conducted for a limited amount of time ● There is a gap in understanding when wearable-derived awareness may become counterproductive	RQ1: Do commercial wearable trackers have any kind of effect on user body awareness and body representations?
Interoceptive Awareness (IA)	Subset of body awareness focusing on internal sensations			
Body Consciousness	Interest and attention to internal sensations and outward body appearance			RQ2: Do commercial wearable trackers improve or worsen the users' relation with their own bodies?
Body Image	Beliefs, thoughts, emotions, attitudes, and cultural values connected to the body	● Some research has explored whether wearables do improve body image ● Other research has highlighted that self-tracking tools may worsen already existing psychological disorders related to body image	● There is little research on body image and wearables in a non-clinical population ● There is a scarcity of studies conducted from a psychological perspective on body surveillance	RQ1: Do commercial wearable trackers have any kind of effect on user body awareness and body representations?
Body Surveillance	Monitoring and attitudes toward one's own body appearance; Connection with self-objectification	● Research has highlighted that self-tracking may encourage the objectification of the body and exert biopower over the individual ● Other research pointed out that not everyone seems to be subjected to the "power" of technology	● Research has explored body awareness, body image and body surveillance separately ● It is not clear if wearables that track body data influence body image positively or negatively	RQ2: Do commercial wearable trackers improve or worsen the users' relation with their own bodies?

for details). Moreover, during the interviews, some interviewees (N = 8, 40%) spontaneously reported body-related issues, some of which were related to their physical health (e.g., migraine, asthma), while others were related to their relationship with their body image (e.g., anorexia and orthorexia). This information turned out to be relevant for the participants' Fitbit experience and that of their own body: we therefore report it in Table 3.

3.3. Experimental design and interventions

We conducted a quasi-experimental study employing a non-equivalent groups pre-test/post-test design. In addition to the participants assigned to the experimental condition (FIT), we also included a non-concurrent control group (CON), which was essential to account for factors that could potentially impact the participants' relationship with their own bodies. The experimental and control group's comparability was maintained through institutional consistency – as all the participants were from the same institution, demographic homogeneity – as participants had similar characteristics, and temporal consistency – as the control group was enrolled exactly one year later to account for effects of seasonal changes, as e.g., in Herschbach et al. (2009) and Netterlid et al. (2013). Using a non-concurrent control is a viable approach when randomization is not feasible, for instance, as in our study, due to budgetary and logistic constraints, as discussed by Bofill Roig et al. (2023). This method is particularly relevant in research aimed at evaluating the impact of a treatment, a medical device, or an intervention, as it serves to enhance the statistical power of the study, when the control group cannot be run concurrently with the experimental group (e.g., Noviani et al., 2023; Shulman et al., 2018; Yang & Oh, 2022).

Participants in the FIT condition came to our office to enroll in the experiment. On that occasion, they were informed that they would be taking part in a study exploring the usage of the fitness tracker in connection with various psychological variables. Participants signed the Informed Consent and then received a fitness tracker (*Fitbit Inspire HR*) and were asked to regularly wear it for the whole 4-month experiment period. The participants had to wear the bracelet throughout the day but could choose not to wear it at night. The Informed Consent contained a description of all the data that the Fitbit would collect, namely: (i) step count; (ii) heartbeat rate; (iii) activity performed (e.g., walking, running, swimming …); and (iv) sleep information (e.g., bedtime, wake up time and sleep stages). All the participants in the FIT group started the trial the same day and terminated it the same day (May 15, 2020–September 17, 2020). Instead, participants in the CON group did not receive any device. All the participants in the CON group started the trial the same day exactly one year after the FIT group (and terminated it the same day after four months, exactly one year after the FIT group). We further provide the detailed consent form on this study's OSF repository[2].

The rationale for the duration of the study was based on several considerations. First, since our study began in May and concluded in September, the 4-month window ensured that data collection primarily occurred during late Spring and Summer, minimizing potential confounding variables such as seasonal affective changes or changes in outdoor activity levels. Given the study's geographical location, there were not drastic seasonal changes within this period that could influence participants' behaviors and moods, which in turn could potentially bias data collection. Second, since longer studies often pose challenges related to participant retention and adherence, we aimed to strike a balance between collecting sufficient data while keeping participants engaged throughout the study: we deemed four months an appropriate compromise. Third, we wanted to minimize risks from potential Fitbit malfunctions, which could compromise data collection.

Since there was no lock-down in the region where our participants resided during the experiment, we believe that the effect of the COVID-19 pandemic on the participants was limited. The first phase of the study was quantitative and structured in three main moments: baseline, deployment, and post-deployment. During the baseline (first week of the study), participants (FIT and CON) were administered an entry questionnaire collecting demographic information (See Section 3.4.2) and a first round of questionnaires and scales on body measures (see Section 3.4.4), which required 20 min to be completed. During the deployment period, all participants carried out their normal everyday activities. Right after the end of the deployment, that is, after four months and within a period of three weeks, all participants in both the FIT and CON conditions were again asked to answer the same questionnaires and

[2] Link to the consent forms on our OSF repository: for the control group: https://osf.io/vjcz4 and for the experimental group: https://osf.io/8ctq4.

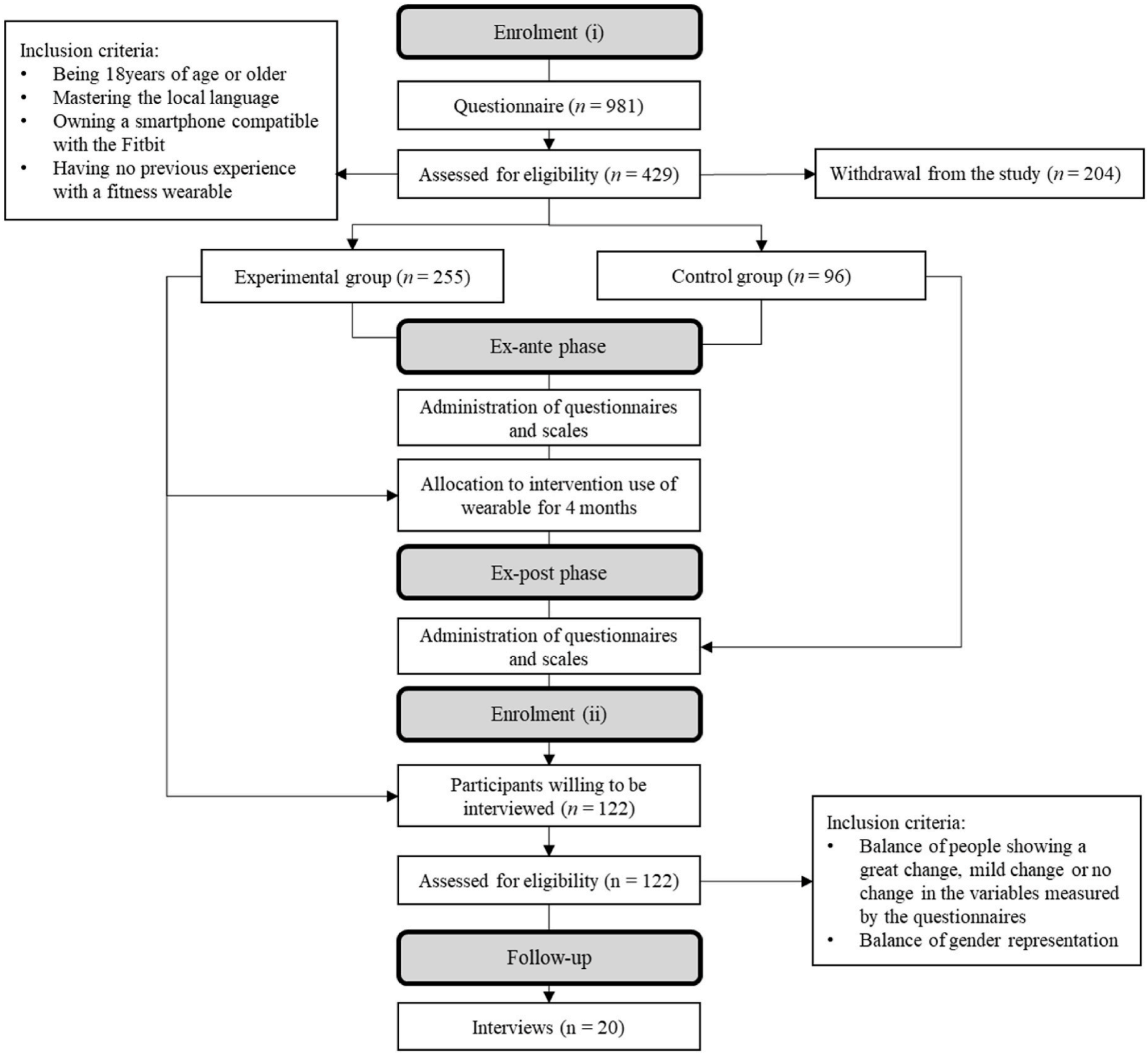

Fig. 1. Flow diagram showing the sampling procedure in the different phases of the study.

Table 2
Participant characteristics.

		Number (%)	Age (SD)	Age missing
Control	Women	56 (58.3%)	23.07 (3.36)	1
	Men	38 (39.6%)	21.92 (3.28)	0
	Other	2 (2.1%)	22 (1.41)	0
	All	96 (29.9%)	22.59 (3.33)	1
Experimental	Women	142 (63.1%)	21.52 (2.52)	1
	Men	82 (36.4%)	21.71 (2.51)	0
	Other	1 (0.4%)	20 (0)	0
	All	225 (70.1%)	21.58 (2.51)	1
All	Women	198 (61.7%)	21.95 (2.86)	2
	Men	120 (37.4%)	21.78 (2.77)	0
	Other	3 (0.9%)	21.33 (1.53)	0
	All	321 (100%)	21.88 (2.81)	2

Percentages are relative to the group (e.g., Women in control group 58.3% = 56/96) or to the total for "All" (e.g., Control 29.9% = 96/321). Missing value counts are reported for Age (no other missing values).

scales administered in the baseline period. Participants in the second phase of the study signed a supplementary Informed Consent and were administered a semi-structured interview (See Section 3.4.2). Upon participation in the experiment, each participant received ~ USD67. Participants who were interviewed after the deployment received a

Table 3
Subsample of participants interviewed.

ID	Gender	Age	Body-related issues
P01	M	22	Migraine
P02	F	22	Eating disorder (in the past)
P03	F	22	Orthorexia (in the past)
P04	M	24	n.d.
P05	F	23	n.d.
P06	F	24	n.d.
P07	M	23	Asthma
P08	F	21	n.d.
P09	M	22	n.d.
P10	M	24	n.d.
P11	F	23	n.d.
P12	M	20	n.d.
P13	F	24	n.d.
P14	F	21	Low blood pressure (fatigue)
P15	M	22	n.d.
P16	M	21	n.d.
P17	M	23	Anxiety, panic attack
P18	F	23	Low blood pressure (fatigue)
P19	F	23	Migraine
P20	M	22	n.d.

supplementary monetary compensation of ~USD27. Participants in the FIT condition received a ~ USD109 Fitbit and were allowed to keep it for personal use after the end of the study. Finally, participants in the control group participated in a lottery having the opportunity to win six monetary prizes of ~USD54 each.

3.4. Apparatus

Each participant was provided with a brand-new Fitbit Inspire HR, which we purchased for the experiment. The choice of Fitbit Inspire HR was driven by multiple considerations. Firstly, Fitbit is a well-established brand in the wearable market, ensuring reliability and consistent data collection. For its characteristics, namely accuracy, reliability, popularity among the public, and access to user data, Fitbit trackers have often been used in self-tracking research (e.g., Day, 2016; Goodyear et al., 2017; Kerner et al., 2019). In addition to that, the specific model allows the monitoring of a plethora of data types and is popular among the public, being a general-purpose fitness tracker with a large user base (Velykoivanenko, et al., 2021). This makes the device an optimal emblematic case of wearable activity trackers.

At the beginning of the experiment, participants had to create an account on the Fitbit portal and grant us access to their data so that we could retrieve the tracker logs from the Fitbit server through the provided APIs. To ensure privacy, we recommended participants to limit the information given to third parties, for example, by using a fake name, giving a temporary e-mail address to create the Fitbit account.

3.5. Measures

To provide a clearer rationale for the selection of specific instruments and questions posed to participants, Table 4 links the measures used in the study to the core of our research questions.

3.5.1. Questionnaires and scales

To measure the constructs relevant to capture participants' relation to their own body, we used two different questionnaires and three scales. They were administered in an online survey through the Qualtrics platform.[3] We administered the French version of the questionnaires, as French is the local language of the participants. When a French version was not available, that is, for the scales measuring body consciousness and body surveillance, we performed a translation following a forward-backward translation technique, as described in Marquis et al. (2005). We provide the translated version of the questionnaire on this study's OSF repository.[4]

We involved four translators: two of them were French native speakers who were proficient in English, while the other two were native English speakers proficient in French. The first author supervised the whole translation process to ensure that the intended concepts would be well captured in the translated version. The researcher explained to the translators that Swiss-French students would answer the questionnaire, so that it would better match the language of the target population. In the first phase, the two native French speakers independently translated the items from English to French. Then, the translators compared their translations and solved any discrepancies,[5] elaborating a French version of the scales. In the second phase, two different native English speakers proficient in French, who had not seen the original copy of the scales, translated the French version of the scales elaborated in the first phase back to English. Finally, in the reconciliation process, all the translators together compared the two versions of the scales to solve any open points[6] and finally produced a single final French version of the scales.

Table 4
Summary of instruments used and links to research questions.

Instrument/Method	Purpose of the instrument/method	Connection to aspects of the research questions
Quantitative instruments		
MAIA (Multidimensional Assessment of Interoceptive Awareness)	To measure participants' awareness of their own bodies and determine whether the attention towards internal bodily signals is beneficial or maladaptive	● To understand if the use of a self-tracking wearable device influences body awareness ● To understand if this change in the participants' body awareness is beneficial or maladaptive
Body Consciousness Questionnaire (Private Body Consciousness and Public Body Consciousness scales)	To measure complementary aspects (to MAIA) of internal body awareness, like how participants attend to the public aspects of their own body	
QIC (Questionnaire d'image corporelle)	To evaluate the participants' satisfaction about their body image	● To understand if the use of a self-tracking wearable device produces changes in participants' body image
Objectified Body Consciousness Questionnaire (Body Surveillance scale)	To measure the participants' experience of the body as an object	● To understand if the use of a self-tracking wearable results in participants surveillance tendencies about their own bodies
Qualitative instruments		
Semi-structured interviews	To find explanations for the results obtained by administering the questionnaires and scales	● To capture the participants' explanations about their changing or non-changing perception and awareness of their own bodies induced by the device
Dialogical Sketching Technique (Interviews)	To enable participants to express their relationship with their body image and with internal sensations	● To understand how the participants perceive their own bodies

Interoceptive awareness. To assess body awareness, we administered the French version of the *Multidimensional Assessment of Interoceptive Awareness (MAIA),* a self-report measure elaborated by Mehling et al. (2012) and translated by Similowski and Laviolette (2012). The French version has psychometric properties close to the original (Edwige et al., 2014). MAIA comprises eight sub-scales (*noticing, not distracting, not worrying, attention regulation, emotional awareness, self-regulation, body listening, trusting*) and 32 items, which are administered with a 6-point frequency scale, ranging from 0 ("*never*") to 5 ("*always*"). The sub-scales are described by the authors (Mehling et al., 2012) as follows: "noticing" refers to the awareness of the body sensations; "not distracting" is the tendency not to use distraction as a strategy to cope with uncomfortable body sensations; "not worrying" represents the tendency not to be emotionally distressed by uncomfortable body sensations; "attention regulation" assesses the ability to control and regulate the

[3] See: https://www.qualtrics.com/, last retrieved April 2023.

[4] See "Supplementary Material 01 - Questionnaires and Scales" on our OSF repository: https://doi.org/10.17605/OSF.IO/Q5FK3.

[5] In this phase, the translators had to solve 11 discrepancies. For example, one person translated from English to French the term "*body build*" as "*taille*", while the other as "*aspect corporel*" (final version).

[6] In this phase, the translators had to solve 5 points of divergence. The discussion ultimately led to changing 6 items that had been translated in the first phase, while the other 13 items were confirmed. For instance, "*côtés de mon visage* » [*facial features* in the English version] was then rephrased in the final version as "*caractéristiques* [de mon visage]", while « *Je m'inquiète rarement*" [*I rarely worry* in the English version] was ultimately rephrased as "*Je suis rarement préoccupé*".

attention paid to body sensations (e.g., refocusing the attention from the body to the surroundings); "emotional awareness" points to the ability to recognize the physiological manifestations of emotions; "self-regulation" is the ability to regulate distress by paying attention to the body; "body listening" is the tendency to listen to the body to gather insight (e.g., regarding one's emotional state); finally, "trusting" concerns one's experience of her body as a safe and trustworthy place. MAIA was chosen as it covers the gap of previously developed questionnaires (e.g., the *Body Awareness Questionnaire*, by Shields et al., 1989), being able to distinguish whether the attention towards internal bodily signals is beneficial or maladaptive. Higher levels of body awareness are mirrored by higher scores obtained in MAIA. Cronbach's alpha of the questionnaire was adequate (α = 0.89).

Body Consciousness. To provide a more accurate and complete measure of the way people are aware of their own body, we decided to measure participants' body consciousness. We therefore administered two scales of the *Body Consciousness Questionnaire* developed by Miller et al. (1981). The first is "Private Body Consciousness", which has 5 items and detects complementary aspects of internal body awareness compared to MAIA (Ainley & Tsakiris, 2013). The second is "Public Body Consciousness," which has six items and measures the extent to which people attend to the public or social (manners, behaviors …) aspects of the body: it is considered closely related to body surveillance, but it refers to the individual's awareness of the body as a social object (Miner-Rubino, Twenge, & Fredrickson, 2002). Higher scores represent greater body consciousness. Cronbach's alpha of the Private Body Consciousness scale and the Public Body Consciousness was adequate (α = 0.73 and α = 0.71 respectively).

Body image. Body image was assessed through the *Questionnaire d'Image Corporelle (QIC)* which was originally developed in the French language and then translated as the "Body Image Satisfaction Scale" (Bruchon-Schweitzer, 1987; Koleck et al., 2002). The QIC questionnaire is a 19-item body image questionnaire used to evaluate the body satisfaction of individuals on a 5-point Likert scale. The questionnaire's total score can range from 19 to 95, with a higher score indicating greater satisfaction with one's own body. Cronbach's alpha of the questionnaire was adequate (α = 0.88).

Body Surveillance. Objectification is how people think about their bodies as objects as bodies are a source of value. One of the most common manifestations of self-objectification is body surveillance, wherein people tend to monitor their bodies from a third-person perspective. To assess this attitude towards the body, we employed the "Body Surveillance" scale, which is part of the *Objectified Body Consciousness Questionnaire* developed by McKinley and Hyde (1996), which measures the experience of the body as an object. The scale is composed of eigth items and uses a 7-point Likert scale, where higher values indicate higher surveillance tendencies. Cronbach's alpha of the scale was adequate (α = 0.81).

3.5.2. Interviews

The first and the second authors conducted three preliminary interviews with three individuals (female = 3; mean age = 31) that volunteered to assess the understandability of the questions, make the necessary changes, and validate the final protocol. We provide further details on our interview protocol through our supplementary material repository.[7] A total of 19 interviews were conducted on site, while 1 interview was conducted online via Skype. We interviewed one participant at a time. The first and the second authors performed all the interviews and recorded them to facilitate the transcriptions. The interviews lasted ~45 min on average for each participant.

Before starting the interviews, the researchers screened the profile of the interviewee emerging from the preliminary data analysis, to grasp an initial picture of the interviewee. In line with the exploratory approach that characterizes this study, we opted for conducting loosely structured interviews to favor the spontaneous expression of participants' use of the wearable in daily life.

The interview was structured in three main phases. After an initial ice-breaking phase, participants were asked about the overall experience they had with the Fitbit and were asked to mention any positive or negative experience concerning its usage. This part was necessary to collect more detailed information about the participant and to formulate the questions in a more familiar way for her, basing the subsequent questions on her mentioned experiences and the specific language she was using.

In the second part of the interview, we focused on the relationship that participants had with their own body. We wanted to understand if the Fitbit affected the image they had of their own body in any way and how the awareness of their internal sensation was shaped by the usage of the tracker. As in the protocol testing, people might find it difficult to verbally express themselves on these topics. Therefore, we provided the interviewees with pens, pencils of assorted colors and paper and asked them to draw the image they had of their own body. In doing so, we did not give strict instructions on how to make the drawings. We drew inspiration from the Dialogic Sketching method (Koulidou et al., 2020), which has been proven to stimulate reflection and expressions of meanings that might be difficult to articulate, as in the case of talking about the relationship with one's own body.

After participants had discussed their drawings, the researcher proceeded to administer the remaining questions. Participants were asked about the relationship they had with their internal body sensations such as breathing, heartbeat and pain. They were asked to provide specific examples of personal experiences to support their answers. Finally, they were asked if the Fitbit had any impact on this relationship, for example, if it made bodily sensations clearer or rather it confused them, if they had learned something new about their own body, etc., as well as an explanation for the changing/non-changing effects of the device.

3.6. Data analysis

We now describe how the data collected in our study were analyzed and the rationale behind the selection of the methodology used. Both quantitative and qualitative data analysis outputs are also provided in our OSF repository.[8]

3.6.1. Quantitative analysis

The quantitative analysis of the data aims to explore the difference between the control and experimental groups for each scale. The comparisons were first made overall, then detailed per gender. In addition, and as a preamble, we briefly analyze the correlations between the scales. The differences between the control and the experimental group in terms of scales measured during the post and pre-deployment phases are assessed using inhomogeneous variances two-sided t-tests for each of the 13 measures. Our choice of *t*-test was influenced by the size of our sample, which was large. In these situations, pre-testing for normality often becomes redundant or even counterproductive, as supported by Rochon et al. (2012). Consequently, we opted to interpret any p-values with caution, trying to avoid any over-interpretation of significant tests. In order to examine these differences by gender and to control for age, multiple regressions were used. The dependent variable was the difference post-minus pre-deployment measures against the age, the group, the gender and the interaction between group and gender. Multiple comparisons between groups for each gender were performed with Tukey adjusted p-values. The entire analysis was performed using the statistical software R (R Core Team, 2020) and the multiple corrections were performed with the emmeans package (Lenth et al., 2022). In

[7] Link to the interview protocol on our OSF repository: https://osf.io/xf286.

[8] See "Supplementary Material 03 - Results" on our OSF repository: https://doi.org/10.17605/OSF.IO/Q5FK3.

addition, a retrospective power analysis was performed using G*Power (Faul et al., 2007) (see Section 4.1.4).

3.6.2. Qualitative analysis

Data from the interviews were analyzed with a Thematic Analysis approach (Braun & Clarke, 2016), as it fits the purpose of the interview, that is, exploring the real-life experiences of individuals, and identifying commonalities and differences among them. The analysis primarily focused on the participants' narratives of their experiences and how these intertwined with their perceptions of their own body and their bodily sensations throughout the 4-month period. Careful attention was paid to participants' interpretations of their own drawings, integrating their comments with the answers to our questions and analyzing them together.

The first author led the analysis, focusing on each participant's personal recollections, considering their story and past experiences. Reading and re-reading the transcriptions yielded a series of annotations and comments. A series of topics, which were not initially included in the interview track, that is, health-related problems and people having issues with their bodies, emerged in this phase.

The notes were then analyzed and synthesized in single statements, referred to as codes, and paired with illustrative excerpts from the original transcript, that is, quotes. At this point, the second author reviewed the initial codes and engaged in discussions with the first author to reach an agreement on their meanings. The discussion regarding the interpretation of the data conveyed by the codes extended beyond this phase, lasting the entire duration of the analysis, and also involved the last author. The *trustworthiness* (Guba & Lincoln, 1982) of our analysis was achieved through prolonged discussions and clarification of any discrepancy until the three authors reached a consensus.

Once all the cases were analyzed, the first author sought connections among them, thus identifying a series of patterns and grouping the codes into key categories. For instance, the first author found that some emergent codes were related to specific moments or events, allowing for the identification of situations when the role of the Fitbit appeared more relevant.

This iterative process led to the reconfiguration and relabeling of the codes. Some codes were discarded due to their irrelevance, vagueness, or misalignment with our research question, such as how participants used the Fitbit to make changes in their habits, which pertains more to behavior change domain.

Finally, the themes were amalgamated to create a more well-defined hierarchy of themes and sub-themes, resulting in four overarching themes. In total, 112 initial open codes were identified from a total of 328 main quotations from original transcriptions. Inter-rater reliability is not reported since the aim of the qualitative study was to delve into the participants' experiences and the meanings they attributed to them, and, in this sense, attempting to reach the numerical reliability of qualitative data may inhibit the interpretations of codes and limit the richness of the analysis (Morse, 2015).

4. Results

Our study combines both quantitative and qualitative methodologies, employing questionnaires and interviews: while the quantitative data offers a structured insight into the changes observed among participants, the qualitative data offers contextual depth, presenting first-hand accounts and interpretations of changing and non-changing dynamics from the participants. Together, they offer a holistic view of the impact of Fitbit on the participants.

Upon analyzing the quantitative data, we observed changes in the body awareness before and after wearing the Fitbit for participants in the experimental group, and especially for female participants, who showed improvements in additional subdimensions of the same construct. Qualitative data support these findings, as participants reported being more aware of their internal body sensations and sometimes used the Fitbit as a tool to seek explanations for unusual sensations. However, no significant changes were found in quantitative data for body image, body consciousness, or body surveillance. The qualitative study confirmed these results, providing explanation and further insights. Participants reported that the Fitbit did not alter their general representation of their own bodies, but provided an abstract image of their bodies, which they considered irrelevant. Moreover, while quantitative results did not indicate any worsening in the dimensions under investigation, participants verbally recounted that they occasionally experienced detrimental effects when a discrepancy occurred between their personal sensations and the data collected by the device.

This section starts with the description of the quantitative data, followed by a discussion of the qualitative findings, which are organized into four main themes.

4.1. Quantitative study

4.1.1. Correlations between measures

We observed significant positive correlations between total body awareness and most associated metrics, except for public body consciousness. Body image, and private body consciousness are correlated to body awareness measures, and several body awareness measures are also correlated. This pattern implies that the measures used in this study tap into a common underlying dimension, that is, how individuals perceive and relate to their bodies. All correlations between the differences of the scales (post-deployment minus pre-deployment) are reported in Table 5.

4.1.2. Comparisons between groups

All the results are reported in Table 6. We remind the reader that the scale is the difference between the post-experimental and the pre-experimental phases. A key metric we employ is the Difference in Differences (DiD), which captures the change observed in the experimental group minus the change observed in the control group. We found that this value was significant for three scales that will be examined. As it can be read in Table 6, for (i) emotional body awareness, the difference was 0.00 (i.e., no difference) in the control group and 0.32 in the experimental group (DiD $= 0.32$, $p < 0.01$). Thus, there was no change in this scale between the pre- and post-deployment in the control group. The scale, however, increased in the experimental group. Secondly, for (ii) total body awareness, the difference was -0.58 in the control group and 0.56 in the experimental group (DiD $= 1.13$, $p < 0.01$). Thus, from the pre to the post-deployment phase, the scale decreased in the control group and increased in the experimental group. Finally, for (iii) self-regulation body awareness, the difference was -0.16 in the control group and 0.06 in the experimental group (est. $= 0.22$, $p < 0.05$). Thus, from the pre to the post-deployment phase, the scale decreased in the control group and mildly increased in the experimental group.

In these three cases, which point to the same construct of body awareness, there was an improvement in the scale trend between the pre- and post-deployment phase, from the control group to the experimental group in the sense that the trend went from negative to flat, flat to positive, or even negative to positive. This means that the participants who wore the Fitbit for four months experienced an improvement in the general awareness of their own bodies, in the emotional awareness and a mild improvement in self-regulation.

The results for the other scales can be interpreted in a similar manner using Table 6. For instance, no other scale exhibited a significant difference between the two groups, suggesting that wearing the Fitbit for four months did not significantly impact factors like body image, body consciousness, or body surveillance.

4.1.3. Comparisons between groups per gender

The decision to analyze results by gender was motivated by the data emerging from the qualitative study, which highlighted that women

Table 5
Pearson correlation of the differences between the pre- and post-deployment phase measurements. The correlations between body awareness measures and their total are a mathematical construction because the total is the sum of the body awareness measures.

		1	2	3	4	5	6	7	8	9	10	11	12
1	NOTICE_BA	–											
2	nDIST_BA	−0.043	–										
3	nWORRY_BA	−0.048	0.0033	–									
4	ATTREG_BA	0.28****	−0.0044	0.022	–								
5	EMOTAWAR_BA	0.18**	0.021	−0.15**	0.16**	–							
6	SELFREG_BA	0.17**	0.027	0.0083	0.26****	0.19***	–						
7	BODYLIST_BA	0.2***	0.023	−0.19***	0.27****	0.25****	0.27****	–					
8	TRUST_BA	0.094	−0.11	0.072	0.13*	0.07	0.19***	0.18**	–				
9	BODYIM	0.023	0.048	0.068	0.089	0.058	0.051	0.021	0.25****	–			
10	BODYSURV	−0.022	0.026	−0.046	0.049	0.12*	0.057	0.063	−0.042	−0.16**	–		
11	PRIV_BC	0.17**	0.089	−0.12*	0.12*	0.28****	0.17**	0.26****	0.11	0.035	−0.13*	–	
12	PUB_BC	−0.053	−0.036	0.023	−0.0091	0.072	0.026	0.11*	0.11*	0.041	0.061	0.25****	–
13	Total_BA	0.47****	0.26****	0.18**	0.55****	0.48****	0.6****	0.59****	0.46****	0.17**	0.061	0.3****	0.077

Significance code for the p-values (not shown) is **** < 0.00001 < *** < 0.001 < ** < 0.01 < * < 0.05 < . < 0.1. In the first column the constructs examined are: (i) the body awareness sub-scales (NOTICE_BA, noticing; nDIST_BA, not-distracting; nWORRY_BA, not-worrying; ATTREG_BA, attention regulation; EMOTAWAR_BA, emotional awareness; SELFREG_BA, self-regulation; BODYLIST_BA, body listening; TRUST_BA, trusting); (ii) BODYIM, body image; (iii) BODYSURV, body surveillance; (iv) the subscales of PRIV_BC, private body consciousness and PUB_BC, public body consciousness; (v) Total_BA, body awareness (total value). (i) the body awareness sub-scales (noticing, not-distracting, not-worrying, attention regulation, emotional awareness, self-regulation, body listening, trusting); (ii) body image; (iii) body surveillance; (iv) the subscales of private body consciousness and public body consciousness; (v) body awareness (total value).

Table 6
Comparisons of the differences between control and experimental groups.

	Control (n = 96) Mean (SD)			Experimental (n = 225) Mean (SD)			Two-sided *t*-test				
	Pre	Post	Δ	Pre	Post	Δ	DiD	Statistic	Df	p-value	
NOTICE_BA	3.57 (0.72)	3.55 (0.72)	−0.02 (0.7)	3.33 (0.87)	3.39 (0.87)	0.06 (0.81)	0.08	0.94	204.18	0.350	
nDIST_BA	2.41 (0.85)	2.31 (0.9)	−0.11 (0.91)	2.31 (0.94)	2.26 (0.93)	−0.04 (0.93)	0.06	0.58	182.45	0.564	
nWORRY_BA	2.92 (1.15)	2.73 (1.21)	−0.19 (0.87)	3.11 (1.21)	2.95 (1.13)	−0.16 (0.86)	0.04	0.34	177.04	0.735	
ATTREG_BA	2.95 (0.82)	2.78 (0.93)	−0.18 (0.74)	2.77 (0.95)	2.76 (0.88)	−0.01 (0.79)	0.17	1.82	192.37	0.070	.
EMOTAWAR_BA	3.39 (0.97)	3.39 (0.89)	0 (0.75)	3.07 (1.06)	3.39 (0.99)	0.32 (0.95)	0.32	3.20	226.82	0.002	**
SELFREG_BA	2.75 (1.1)	2.6 (1.12)	−0.16 (0.85)	2.45 (1.16)	2.51 (1.01)	0.06 (1)	0.22	1.98	210.42	0.049	*
BODYLIST_BA	2.56 (1.27)	2.58 (1.08)	0.02 (0.95)	2.22 (1.16)	2.35 (1.12)	0.13 (1.07)	0.11	0.95	201.57	0.344	
TRUST_BA	3.61 (1.08)	3.67 (1.13)	0.06 (0.85)	3.57 (1.15)	3.76 (1.09)	0.19 (0.97)	0.13	1.23	203.33	0.220	
BODYIM	57.8 (4.62)	57.45 (3.97)	−0.35 (4.48)	72.25 (10.96)	72.02 (10.79)	−0.23 (7.12)	0.12	0.19	274.62	0.852	
BODYSURV	4.01 (0.66)	4.01 (0.73)	0 (0.57)	4.3 (1.04)	4.26 (0.96)	−0.05 (0.69)	−0.04	−0.60	212.40	0.547	
PRIV_BC	4.79 (0.88)	4.75 (0.92)	−0.04 (0.76)	4.62 (1)	4.72 (1.01)	0.11 (1.01)	0.14	1.39	235.59	0.167	
PUB_BC	4.55 (1.22)	4.46 (1.34)	−0.09 (0.84)	4.58 (1.15)	4.57 (1.08)	−0.01 (0.88)	0.08	0.79	186.14	0.429	
Total_BA	24.18 (4.21)	23.61 (4.14)	−0.58 (2.86)	22.83 (4.6)	23.38 (4.6)	0.56 (3.37)	1.13	3.08	209.96	0.002	**

Differences (Δ) are post minus pre-deployment phase. The Difference in Differences (DiD) are tested with a two-sided *t*-test with inhomogeneous variances (Welch correction). Significance code is *** <0.001 < ** <0.01 < * <0.05 <. < 0.1. In the first column the constructs examined are: (i) the body awareness sub-scales (NOTICE_BA, noticing; nDIST_BA, not-distracting; nWORRY_BA, not-worrying; ATTREG_BA, attention regulation; EMOTAWAR_BA, emotional awareness; SELFREG_BA, self-regulation; BODYLIST_BA, body listening; TRUST_BA, trusting); (ii) BODYIM, body image (iii) BODYSURV, body surveillance; (iv) the subscales of PRIV_BC, private body consciousness and PUB_BC, public body consciousness; v); Total_BA, body awareness (total value). (i) the body awareness sub-scales (noticing, not-distracting, not-worrying, attention regulation, emotional awareness, self-regulation, body listening, trusting); (ii) body image; (iii) body surveillance; (iv) the subscales of private body consciousness and public body consciousness; (v) body awareness (total value).

were able to formulate a higher number of reflections about body sensations compared to men, and further supported by literature suggesting inherent physiological, psychological, and sociocultural differences between genders with reference to how they relate to their body, such as their body image (Feingold & Mazzella, 1998) and body awareness (Fiskum et al., 2023; Grabauskaitė et al., 2017).

All the results are shown in Table 7. The Difference in Differences between the control and the experimental group is significant for five scales within one or more gender categories. For (i) noticing body awareness, in the gender "other", the difference was −0.38 in the control group and 1.75 in the experimental group (DiD = 2.13, $p < 0.05$). In (ii) "not worrying" body awareness, for the gender "other", the difference was −0.18 in the control group and 1.34 in the experimental group (DiD = 2.67, $p < 0.05$). In (iii) attention regulation body awareness, for women, the difference was −0.07 in the control group and 0.44 in the experimental group (DiD = 0.26, $p < 0.05$). In (iv) emotional body awareness, for women, the difference was −0.12 in the control group and 0.24 in the experimental group (DiD = 0.36, $p < 0.05$) and, for the gender "other", the difference was −0.1 in the control group and 2.18 in the experimental group (DiD = 2.28, $p < 0.05$). In (v) total body awareness, for women, the difference was −1.18 in the control group and 0.63 in the experimental group (DiD = 1.81, $p < 0.01$), and, for the gender "other", the difference was −4.88 in the control group and 3.45 in the experimental group (DiD = 8.33, $p < 0.05$).

In each case related to body awareness, there was always an improvement from the control group to the experimental group. This improvement was evident in the form of the trend going from negative to flat, flat to positive, or even negative to positive. Upon closer examination of gender differences, it was found that women in the experimental group experienced this improvement in body awareness and emotional body awareness, with a mild increase in self-regulation and attention regulation. A similar improvement for these subscales was not observed in men. As for the gender "other", we suggest taking the results with caution, due to the small sample size of the gender "other" category (only three observations).

These quantitative results give us a clear metric-based insight into the changes in body awareness and related constructs. However, it is also essential to understand the lived experiences and personal

Table 7
Multiple comparisons between Difference in Differences (DiD) between the control and experimental groups per gender.

		Control Est. (SE)	Experimental Est. (SE)	Δ	Statistics	Df	p-value	
NOTICE_BA	Women	−0.04 (0.11)	0.09 (0.07)	0.13	1.04	312	0.299	
	Men	0.03 (0.13)	0.01 (0.09)	−0.03	−0.18	312	0.861	
	Others	−0.38 (0.55)	1.75 (0.78)	2.13	2.24	312	0.026	*
nDIST_BA	Women	−0.33 (0.13)	−0.07 (0.08)	0.27	1.79	312	0.075	.
	Men	0.27 (0.15)	0.01 (0.1)	−0.26	−1.45	312	0.149	
	Others	−0.83 (0.65)	−1 (0.92)	−0.17	−0.15	312	0.88	
nWORRY_BA	Women	−0.18 (0.12)	−0.18 (0.07)	−0.01	−0.04	312	0.967	
	Men	−0.18 (0.14)	−0.12 (0.1)	0.05	0.32	312	0.75	
	Others	−1.33 (0.61)	1.34 (0.86)	2.67	2.52	312	0.012	*
ATTREG_BA	Women	−0.25 (0.11)	0.01 (0.07)	0.26	2.04	312	0.042	*
	Men	−0.06 (0.13)	−0.03 (0.09)	0.03	0.17	312	0.861	
	Others	−0.07 (0.55)	0.44 (0.78)	0.51	0.54	312	0.592	
EMOTAWAR_BA	Women	−0.12 (0.12)	0.24 (0.07)	0.36	2.5	312	0.013	*
	Men	0.24 (0.14)	0.41 (0.1)	0.17	0.99	312	0.321	
	Others	−0.1 (0.63)	2.18 (0.89)	2.28	2.1	312	0.037	*
SELFREG_BA	Women	−0.24 (0.13)	0.08 (0.08)	0.32	2.06	312	0.04	*
	Men	−0.04 (0.16)	0.04 (0.11)	0.08	0.41	312	0.684	
	Others	−1 (0.68)	−0.21 (0.97)	0.79	0.67	312	0.506	
BODYLIST_BA	Women	−0.1 (0.14)	0.2 (0.09)	0.3	1.8	312	0.073	.
	Men	0.34 (0.17)	0.02 (0.11)	−0.32	−1.61	312	0.108	
	Others	−1.33 (0.72)	−0.35 (1.02)	0.98	0.79	312	0.433	
TRUST_BA	Women	0.08 (0.13)	0.27 (0.08)	0.19	1.23	312	0.219	
	Men	−0.03 (0.15)	0.05 (0.1)	0.09	0.49	312	0.624	
	Others	0.17 (0.66)	−0.69 (0.93)	−0.86	−0.76	312	0.45	
BODYIM	Women	−0.35 (0.89)	0.16 (0.55)	0.51	0.48	312	0.63	
	Men	−0.53 (1.05)	−1.05 (0.72)	−0.53	−0.41	312	0.68	
	Others	1 (4.58)	7.97 (6.48)	6.97	0.88	312	0.38	
BODYSURV	Women	−0.1 (0.09)	−0.07 (0.06)	0.02	0.23	312	0.819	
	Men	0.08 (0.11)	0.03 (0.07)	−0.05	−0.4	312	0.687	
	Others	−0.07 (0.46)	−0.19 (0.65)	−0.13	−0.16	312	0.874	
PRIV_BC	Women	−0.02 (0.13)	0.1 (0.08)	0.12	0.79	312	0.428	
	Men	−0.04 (0.15)	0.1 (0.11)	0.14	0.74	312	0.462	
	Others	0 (0.68)	0.99 (0.96)	0.99	0.84	312	0.399	
PUB_BC	Women	−0.09 (0.12)	−0.04 (0.07)	0.04	0.32	312	0.752	
	Men	−0.06 (0.14)	0.04 (0.1)	0.09	0.55	312	0.583	
	Others	−0.67 (0.62)	1.15 (0.87)	1.82	1.7	312	0.09	.
Total_BA	Women	−1.18 (0.44)	0.63 (0.27)	1.81	3.5	312	0.001	**
	Men	0.57 (0.52)	0.38 (0.35)	−0.19	−0.3	312	0.762	
	Others	−4.88 (2.26)	3.45 (3.2)	8.33	2.12	312	0.034	*

The underlying model is a multiple regression (DV = DiD, IV = group, gender, group*gender, age). The p-values are adjusted by the Tukey method. Significance code is *** <0.001 < ** <0.01 < * <0.05 <. < 0.1. In the first column the constructs examined are: (i) the body awareness sub-scales (NOTICE_BA, noticing; nDIST_BA, not-distracting; nWORRY_BA, not-worrying; ATTREG_BA, attention regulation; EMOTAWAR_BA, emotional awareness; SELFREG_BA, self-regulation; BODYLIST_BA, body listening; TRUST_BA, trusting); (ii) BODYIM, body image; (iii) BODYSURV, body surveillance; (iv) the subscales of PRIV_BC, private body consciousness and PUB_BC, public body consciousness; (v) Total_BA, body awareness (total value)..

reflections of the participants. The interviews aim to shed light on these, offering a more nuanced view.

4.1.4. *Power analysis for the body awareness scale*

To ensure the rigor of our study, we performed additional analysis. Specifically, we conducted a *t*-test comparing the DiD between the control and experimental groups on the total body awareness scale (DiD = 1.13, $p < 0.01$; see Section 4.1.2 and line “Total_BA” of Table 6). We focused on this scale because significant differences emerged between the two groups, warranting further scrutiny. As Table 6 shows, the standard deviations were 2.86 for the control group and 3.37 for the experimental group, and that the observed DiD was 1.13. Given these parameters, the resulting effect size is 0.364, placing it between a small (0.2) and medium (0.5) effect size, according to Cohen’s convention (Cohen, 1988). The power of the test for this effect was measured at 0.85. Since an accepted power for such tests typically ranges between 0.80 and 0.95 (Cohen, 1988), this result affirms that our sample size of 96 (control group) and 225 (experimental group) were appropriate.

4.2. *Qualitative study*

Consistent with our quantitative findings on improved body awareness, both female and male participants reported an improved body awareness after the use of the Fitbit during the interviews. Qualitative data analysis revealed a variety of reflections related to the participants’ awareness of their internal body sensations, with special attention to the heartbeat rate, the sleep cycles, and the calorie intake and burn. These reflections, however, were mostly elaborated by female participants, somehow highlighting greater awareness of their inner body. By contrast, the majority of participants declared that wearing the tracker did not influence their body image. In this sense, qualitative findings mirror what was found by quantitative data analysis, but provide a more complex picture of the relationship between the participants’ body and the wearable.

We categorize the findings in four main themes, *testing one’s body awareness*, *looking for explanations*, *restoring order*, and *narrowing body images*. A summary of the qualitative findings can be found in Table 8.

4.2.1. *Testing one’s body awareness*

The participants who experienced an increased awareness of their body processes, mentioned that such an increase was the result of the usage of the Fitbit as a sort of digital data-driven mirror to ascertain bodily sensations as they occur. Several of these participants reported that they already had a good perception of their own body processes, often showing a “testing” attitude in assessing their own ability to accurately determine their body signals. The integration of the Fitbit in their everyday life somehow strengthened this attitude, triggering a series of latent questions about their body, as explained by P06 [F]: “*I*

Table 8
Summary of qualitative findings.

Construct	Theme	Description	
Body awareness	"Measuring accuracy"	*Typology of participants*	Participants who reported no physical issues had no objectives for using the device.
		Reasons for usage	As a generic means of being more aware of their body and, specifically, to "test" the accuracy of their physical sensations.
		On what occasions	While doing physical activity or in the morning to check the sleep cycles.
Body awareness	"Looking for explanations"	*Typology of participants*	Participants with physical issues and "healthy" individuals.
		Reasons for usage	Looking for explanations for eerie or unusual feelings and psychological states.
		On what occasions	In relation to unexpected sensations or events that could have an impact on their bodies.
Body awareness	"Restoring order"	*Typology of participants*	Participants who reported health-related issues, like eating disorders, respiratory issues, migraine.
		Reasons for usage	To explain disturbing sensations and as an "emotional aid" that could bring clarity among chaotic and disorienting sensations.
		On what occasions	In relation to disturbing feelings or body signals the meaning of which was unclear.
Body image and surveillance	"Narrowing the representation of the body"	*Participants' body image*	Specific parts of the body have a meaning for the participants and connect to their identity.
		Healthy bodies	The Fitbit does not affect how people think about the appearance of their own bodies but narrows their representations to the dimension of "healthiness".
		Effects on the participants.	Participants considered data gathered by the Fitbit not particularly personal and were not worried by a possible data leakage.

mean I never used things to understand myself (…) *I think I was just curious to see how good I was at sensing my body … anyway, as I do a lot of sport.*"

"Tests" of body awareness could occur at any time, even though they were mostly linked to physical activity. For example, some participants evaluated their skills in guessing their own heart rate or the effort they put into exercising, which was related to the degree of post-workout fatigue that they perceived, by looking at the data gathered by the tracker and comparing them with how they felt. Participants claimed being pleased if they could find a match between their subjective experiences and the data, which could reinforce the idea that they had a high level of body awareness, as in the case of P20 [M], who declared that he found a correspondence between how he felt, and the data displayed by the Fitbit most of the time.

The tracker, however, did not always confirm their sensations. A mismatch between the two "sources of information" (the body and the Fitbit) could constitute an opportunity for reflection and for learning something about how the body functions and its core processes. This is the case of P07 [M], who discovered through the Fitbit that there are multiple phases of sleep, and that the quantity of sleep may be not correlated with his sense of tiredness. Quite similar words were used by P11 [F] who, instead, noticed that she was not aware, as she believed, of how much effort she put into her running sessions: "[I notice] *that* [after the physical activity] *I was too out of breath or too tired or I had cramps in my legs, etc. when I started using the Fitbit, I realized that my heart rate sped up very often during physical activity (…) once I looked at my Fitbit and saw that I had exceeded my limit, but I didn't realize it (…) I know that the heart shouldn't beat too hard, otherwise you get tired and that can lead to feeling sick … like I get a headache.*" Wearing the Fitbit often triggered a series of questions related to the "reliability" of body awareness and the capacity to listen to the body. The latter is a dimension that could be framed as "interoceptive accuracy", which is the ability to accurately detect one's bodily signals (Garfinkel et al., 2015). In this sense, being able to "see" the sleep cycles was particularly appealing, as sleep was considered as something beyond conscious control and awareness. The notion of uncovering hidden aspects, like the various sleep stages experienced throughout the night, intrigued the participants as it could bring to light body mechanisms of which they were previously unaware. In sum, the device positively impacted the overall body awareness of these participants.

However, several participants stated that they did not learn anything about their body by testing their awareness through the device, as reported by P18 [F], who expressed disappointment with her sleep data, noting discrepancies between her perceived quality of sleep and the scores displayed on the application. Similarly, other participants expected that the Fitbit could detect physiological changes following certain life events (e.g., an exam at the university), which they knew could physically affect their bodies, by raising, for instance, their heart rate. However, these expectations were not satisfied: for instance, P14 [F] reported: "*I was wearing the watch during the examination period. And once I remember that right after* [the exam] *I looked at the Fitbit to see if it had changed … And* [for the bracelet] *nothing had changed …) and I was, like, but I felt that something happened within me*". For these participants, the Fitbit appeared as a sort of black box, whose mechanisms for detecting their body processes remained obscure. Consequently, they did not experience any increase in their body awareness. Mismatches between data and personal sensations could lead these participants to frustration and confusion, making it difficult to learn much from the data. In such a case, participants could lose trust in the tracker and seek justifications for the discrepancies, by saying, for instance, that the Fitbit did not function properly.

4.2.2. Looking for explanations

Several participants attributed to the Fitbit the ability to give answers to complex questions about their body states, providing guidance for understanding their own body. These participants tried to understand specific eerie or unusual body feelings, like negative emotional or physical states (e.g., fatigue), finding reassurance in the "answer" provided by the wearable. Together with increased body awareness, therefore, these participants used the Fitbit to enrich their knowledge about their own body.

An example is offered by P01 [M], who reported an episode where he questioned the quality of his sleep despite sleeping the recommended hours. After consulting his Fitbit, he realized that he had woken up multiple times during the night, which confirmed his feelings of fatigue. Similarly, P18 [F] described how she looked at the Fitbit to better understand why she felt bad during cardio activities, noticing a correlation between certain heart rates and sensations of discomfort.

By the same token, other participants said that they looked at the data gathered by the tracker not only when they wanted to understand a specific body process or sensation, but also when they felt more vague and complex feelings, such as being stressed (P07 [M]) or in a negative mood (P13 [F]) without knowing the reason: P13, for instance, expressed that the Fitbit helped her discern between the psychological and physical reasons behind her body sensations.

For some participants, these explanation attempts did not address only extemporaneous feelings, but extended over time to embrace events having a sort of somatic relevance. P02 [F], for instance, mentioned what happened after the holiday with her friends: "[During that period], *I was sleeping an average of 3 h a night … and I mean, I was aware of it, I knew that but without really knowing it … I don't know if what I am saying makes sense. Then during the week, I didn't look at the watch because I thought that I didn't go there to do that … and when I came back, I had a look at the watch, and I saw that my quality of sleep was really low and that it had had an impact on a lot of little things … I mean, at that time I was exhausted, I was in a bad mood, I had my hair falling out, I wasn't hungry at all …*". As stressed by P02 [F], the data collected by the Fitbit presented an opportunity for her to acknowledge her previous unhealthy sleep habits, prompting a process of reflection that eventually led her to uncover a plausible explanation for the unsettling disturbing sensations that she had been experiencing.

Most of the attempts to explain unusual physical feelings were related to the analysis of the sleep cycles and fatigue or to the heartbeat. When the feelings referred to the quality and quantity of rest, data analysis did not cause any concern. Whatever the feedback given by the bracelet, this offered the basis for formulating plausible explanations that reassured the participants, eventually raising their body awareness and knowledge in the long term. When the stimulus was related to the heart, instead, it mostly caused fear, leading to the immediate consultation of the bracelet: in this case, if participants believed that the feeling was confirmed by the data (e.g., a higher-than-usual heart rate), the negative feeling was strengthened, leading to anxious reactions and overthinking or rumination. Conversely, a mismatch between the physical feeling and the data could have a calming effect stopping the explanation-seeking processes. Here, the wearable rarely led to increased body awareness and knowledge, as it regulated (by mitigating or amplifying) the participants' emotional responses to situations involving potential harm or discomfort to the body. An illustrative example for both cases comes from P03 [F]: *"I was in the train, in the morning, it was seven o'clock, I had my mask on, I couldn't breathe, I started to feel dizzy, I said to myself that I was going to pass out, I look at the pulse and I saw that I had sixty-two beats per minute, I said to myself that it was not normal because sixty-two is when you wake up, it is too low (…) I knew that it was too low, and I thought, what should I do … ? … but then I saw on the Fitbit that it was getting better, so it was fine … So, I like* [the Fitbit] *because you can control the pulses (…) and that reassures me a little bit."*

In sum, differently from those participants who simply used the device to test their body awareness skills, several participants used the Fitbit as a tool to find answers to (mostly unpleasant) unusual feelings, or situations that could be harmful for their body.

4.2.3. Restoring order among chaotic feelings

Several participants, during the interview, spontaneously reported having health and body-related issues. For these people, their relationship with their physical reactions was troublesome, if not chaotic and disorienting, whereby body signals could hold negative value or significance. Eight participants reported these kinds of health issues: P02 [F] has had eating problems for 10 years, while P03 [F] had a past of orthorexia; P01 [M] and P19 [F] had chronic migraine; P07 [M] had respiratory problems; P14 [F] and P18 [F] had anemia and low blood pressure, causing fatigue and exhaustion; P17 [M] suffered from panic attacks. Most of these participants used the Fitbit as a tool that could help them not only explain worrying or particularly disturbing physical states, but also bring clarity to their inner world, which could become chaotic from time to time, eventually experiencing a positive impact on their everyday life.

Some of these participants were primarily motivated by the desire to regain control over their bodies, which they perceived as unpredictable, often leading to undesirable consequences and confusing feelings. It is worth noticing that they mostly could not find any psychological relief or effective solutions to counteract their health issues by consulting their doctor, as explicitly reported by P01 [M], who said that he was not reassured by his doctor's feedback. Similarly, P18 [F] expressed dissatisfaction with her doctor, as she consulted him about frequent fatigue and blurry vision, only to be advised to "*Eat some salt*".

Data collected by the wearable, instead, constituted a way of finding comfort in participants' "actual" physical situation. Some participants were aware that a new health problem could be detected by a series of body signals, which were nevertheless difficult to identify. The Fitbit could therefore support these individuals by helping them monitor certain body signals, so as to give them structure and prepare them for what was happening, possibly predicting a harmful situation. P17 [M], for example: *"I suffer from anxiety attacks and panic attacks … There are times when for half an hour at maximum I feel my heart beating very, very fast or maybe it's just my head that starts worrying and this leads my heart to beat very fast, and there are other symptoms. For example, I feel that my throat is closing, and you need a lot of air (…) and* [with the Fitbit] *I realized that, in fact, in terms of heart rate, it was actually going quite well … and it didn't last as long as I thought … So, in a sense, it allowed me to put all the things into perspective, because I just had the feeling that my heart was beating much faster than it actually was."* For this participant, looking at the data and learning that, in fact, his assessments of his physical state were biased or incorrect had the effect of bringing organization to the chaotic feelings he had. This reassured him that nothing serious was happening in his body, and that the nature of the feeling was psychological and not physically related.

In sum, the qualitative findings enrich our quantitative data by providing participants' reasons, reflections, and deeper insights into the observed changes. We found that the data gathered by the wearable could help these participants find "reasons" for feelings that they have been struggling to understand despite having consulted their doctor. Their questions about their bodies were intimately connected to their personal history and framed the role of the Fitbit into a general attempt to better understand themselves, from a somatic point of view. In other words, for participants who reported health conditions, the numbers provided by the wearable not only increased their self-knowledge but also offered an emotional aid and had a positive influence on their daily life.

4.2.4. Narrowing the body image

The Fitbit supported the body awareness of several participants by providing them with information about how the human body functions, which in turn improved their ability to "listen" to their own body. On certain occasions, this enhanced awareness shifted from a focus on the body signals in the "here and now" to a more general impact on their body image. This said, it seems that the Fitbit did not increase participant surveillance attitude, as no significant effect on this construct was found in the quantitative study. By reflecting on the data collected by the device, participants did not become preoccupied with their physical appearance or how their bodies might be perceived from a third-person perspective. The data emphasized a biomedical view of the body as an organism capable of functioning optimally. As P14 [F] said, the Fitbit could be associated with a sort of digital clinician "*who says (…) what is good and what is not good*", thus providing a prescriptive picture of how the body should be "treated." This biomedical view of the body emerges from the accounts of various participants.

More specifically, interacting with the tracker strengthened a specific perception of the body as either healthy or unhealthy. P11 [F], who studies medicine, noted that the Fitbit data heightened her awareness of her health. Similar reflections were shared by P05 [F], who declared that she had the impression that her body was healthier when she reached the goals set and/or tracked by the device - and reinforced a negative vision of her body when such goals were not achieved. For P17 [M] the wearable revealed some important aspects of his health that made him reconsider his well-being, thus improving the image of his body: "*And I think, well, it also made me realize that I'm doing well, and that I am doing what I need to stay in shape. The number of steps, walking, running* (…) *and I find that my breathing is better, that my heart rate is stable and similar things*".

However, for several participants the Fitbit conveyed a negative image of their bodies – although this was not confirmed globally by the quantitative study. By providing a "standard" of body functions, to which participants felt they had to conform, the device could enforce the idea that they were doing something bad for their own health. When P03 [F] noticed that she could not reach the 10,000 recommended daily steps, she felt immediately bad.

Not only were these participants worried about not respecting the standard provided by the Fitbit, but they also started feeling a certain mistrust towards a system that does not take into account the peculiarities of their own body functions. For instance, P16 [M] said that he was skeptical about the accuracy of the system calculating the calories burned, suspecting that it could overestimate them due to his naturally high and rapid pulse rate. A similar experience was reported by P18 [F] concerning her experience with the data collected around the menstrual cycle. The Fitbit consistently misinterpreted her shorter, yet regular cycle, requiring her to manually input data. Finally, P08 [F] explained that he is a person who does not sleep the "standard" 8 h, therefore the Fitbit scores were not meaningful to her as they did not suit his peculiar habits.

During the dialogic sketch session, it became evident that the participants felt that the Fitbit was unable to provide personalized body images, as a contrast to how they personally conceptualized their own bodies. Participants' body representations were often "tagged" by highlighting specific body parts that held significance for their inner

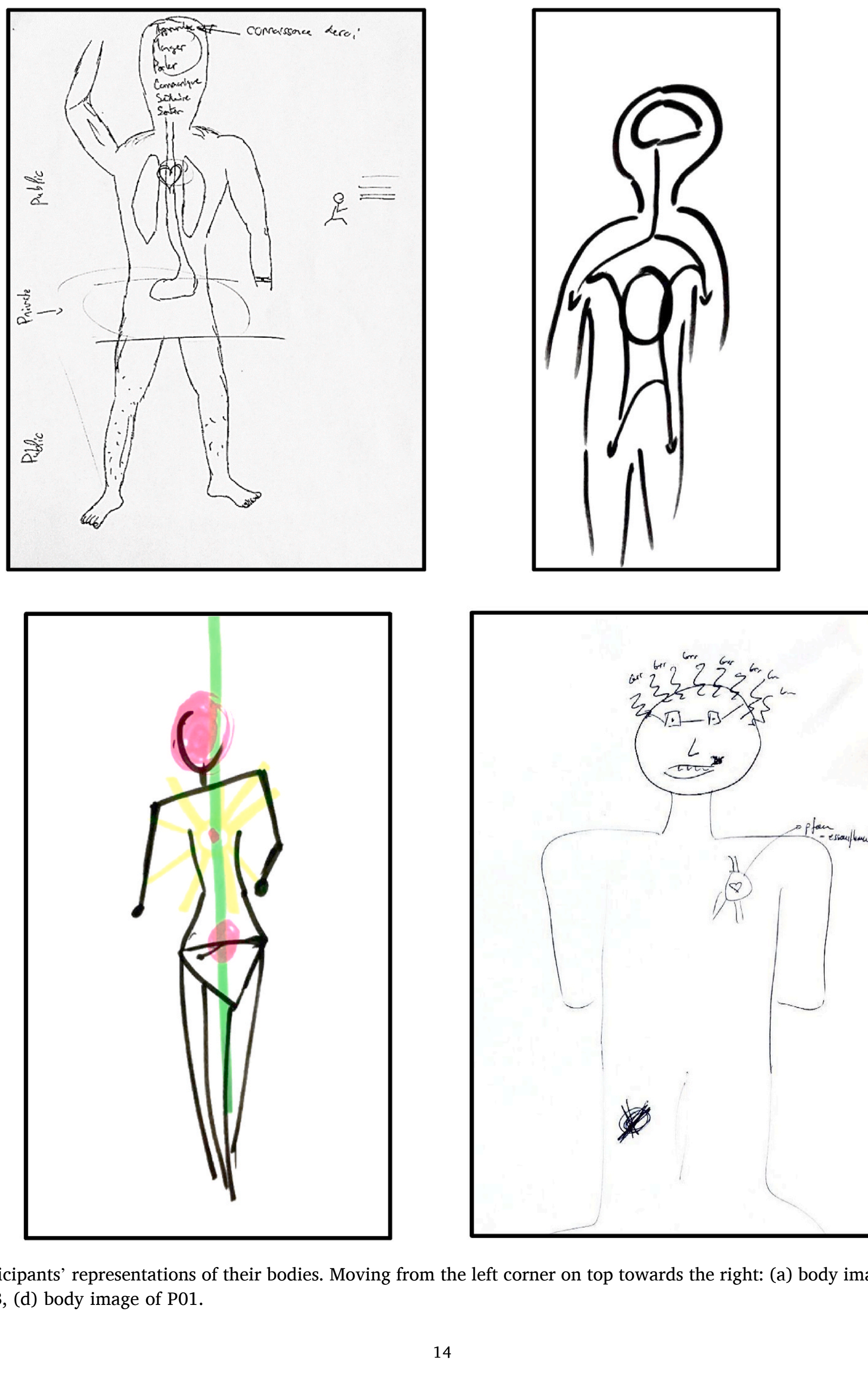

Fig. 2. Samples of the participants' representations of their bodies. Moving from the left corner on top towards the right: (a) body image of P07, (b) body image of P19, (c) body image of P03, (d) body image of P01.

lives. Illustrative examples were offered by a group of participants who reported having mild health conditions. In his drawing (Fig. 2a), P07 [M] graphically emphasized the areas around the lungs, the heart, and the brain as particularly relevant to his bodily experience. The lungs, for instance, were vital organs that required care (as he suffered from asthma). Similarly, P19 [F] (Fig. 2b) wanted to represent the centrality of the brain and its impact on the rest of the body, as she declared suffering from migraines. P03 [F] (Fig. 2c) interestingly used different colors to highlight the areas in the body that have a particular meaning for her, as each part was bound to a particular function. For instance, the head and the solar plexus were important and intimately tied to her identity, as she said: "*When I touch here* [abdomen] *I say, that's me, that's really me (…) because it's the part where you can really stay in touch with your feelings (…) when something is wrong, you can feel it, and I can feel it there a lot*". Finally, the separation between the inner and outer sides of the body was highlighted by P01 [M], who made two different drawings for each of them: in the drawing reported in Fig. 2d, we can notice the painful and most problematic parts, such as the knee, the head, and the heart.

As opposed to these idiosyncratic descriptions, for most of the participants the Fitbit appeared to convey anonymous images of their bodies, narrowed to a set of physiological and biological processes, which are tied to the levels of energy, well-being or discomfort, strength, or fragility. "*I can see more the physical or the sporty side of me (…) maybe I can tell, ok, I am probably healthy (…) all these data, the number of steps, the heartbeat (…) it could be a little abstract, but this is the image that the Fitbit conveys*". (P03 [F]). Most participants evaluated the body images fed back by the device as intrinsically uninteresting, as if they were not actually related to themselves or their identity and not linked to the image that they had of their own body. This kind of representation provided by the device also led participants to consider the sharing of body-related data as irrelevant. In fact, most of the participants felt that the data could not be of interest to anyone else, since they did not convey a "true" image of their body: "[By looking at the data] *one can see my level of activity, the heart rate … I mean* [if another person looked at this data]*, maybe she would understand whether I am stressed out or not, these kinds of things … but I don't think that these data are that interesting*" (P09 [M]).

In sum, while quantitative data indicated no significant change in body image, the interviews revealed that Fitbit usage narrows the participants' representation of their bodies to the dimension of "healthiness": a minority of participants experienced either an improved or worsened body image, especially in relation to their health, consequently also experiencing positive or negative consequences in daily life. The majority of them, however, could not recognize themselves in the body image depicted by the Fitbit because the system did not reflect their body-related idiosyncrasies.

5. Discussion

By conducting a 4-month mixed-methods study, we investigated how a group of young individuals engaged with a commercial wearable device for the first time and how this interaction was relevant for their relationship with their bodies. Our study contributes to self-tracking research in two main ways. First, we offer a comprehensive understanding of how wearable self-tracking devices affect the users' relationship with their own bodies. Unlike previous studies that focused on isolated psychological body constructs, we examined the effect of the wearable device on body awareness, consciousness, surveillance, and image collectively. As for our first RQ *(Do commercial wearable trackers have any effect on users' body awareness and body representations?)*, we found in the quantitative study that the Fitbit impacts body awareness especially in women, but does not have an effect on body consciousness, surveillance, and image.

Secondly, we conducted an in-depth qualitative investigation of the diverse effects (or non-effects) that these tools have on individuals, in answer to our second RQ (*Do commercial wearable trackers improve or worsen the users' relation with their own bodies?)*. We discovered that several individuals improved their body awareness as well as the knowledge of their own body. Other participants with chronic illnesses also experienced positive effects, while others became more worried about their health following the usage of the Fitbit. Nevertheless, for many participants, the device primarily enhanced their body awareness without significantly altering their perception of their bodies.

More precisely, the alignment of quantitative and qualitative results supports a coherent line of argumentation. In comparison to the control group, participants in the experimental condition experienced an improvement in overall body awareness, as well as in the subscales of emotional body awareness and self-regulation. However, further analysis revealed that the enhanced body awareness was more pronounced among female individuals, who also showed improvements in the subscales of emotional awareness, self-regulation, and attention regulation. Conversely, body image, body consciousness and body surveillance did not significantly change after wearing the tracker. Therefore, these quantitative results support the claim that activity trackers might in fact enhance the users' awareness of their own bodies (Esmonde, 2019; Ruckenstein, 2014), with a minor risk of developing excessive body surveillance habits.

Qualitative data revealed that the Fitbit provided participants with a frame to interpret internal feelings and offered explanations for eerie bodily signals. Participants used the device not only to test their capabilities of detecting "correct" body signals, but also to find explanations for unusual or unexpected feelings. Despite the reflections prompted by the Fitbit regarding body symptoms lacking scientific rigor (a pitfall already reported by Choe et al., 2014), the Fitbit feedback appeared to be comforting, especially for individuals who suffered from various medical conditions. Nonetheless, the Fitbit offered a "narrow" image of the participants' body, as reported by previous literature (e.g., Reiby et al., 2022). In most cases, this narrow body image did not reflect how the participants saw their own bodies, making them psychologically detached from the collected data, which were considered irrelevant. This may explain why, in the quantitative study, we could not find any significant change (except for body awareness) in the other body constructs under examination, which point to how individuals think about their body more in depth.

We will discuss these results thoroughly in the next section.

5.1. Relevance of gender for body awareness

While our initial research questions did not specifically target gender as a primary determinant, as we delved deeper into the analysis of our qualitative findings the role of gender emerged as relevant with reference to body awareness, as women appeared to reflect more on their inner body sensations than men: this led us to further analyze the quantitative data by comparing responses across gender. This observation aligns with the nature of exploratory research including a qualitative study, where not all outcomes may be foreseen. The difference in response across genders was substantial, especially when looking at the specific breakdown of the scales by gender, revealing the relevance of the female gender. The sub-dimensions of body awareness that exhibited the most change for women were: "emotional body awareness", "self-regulation" and, to a lesser extent, "attention regulation". This means that female participants in the experimental group perceived a heightened awareness of the links between body-related feelings and psychological states (i.e., emotional awareness), and were more able to regulate distress by paying attention to the body (self-regulation), compared to the female participants in the control group. Additionally, although the difference was relatively small, female participants also showed an improvement in the attention regulation sub-scale, as they felt they were more able to sustain and control attention to body-related feelings with respect to external stimuli. These results contrast the findings of Busch et al. (2020), who observed no differences in certain sub-dimensions of body awareness after participants used a tracker after 6 weeks. However, it is important to note that their study did not involve the use of a wearable device but rather a fitness app, which may explain why the results diverge. Moreover, it is possible that the duration of the Busch et al. (2020) study was too short to observe this kind of effect. The role of gender can be framed in prior studies concluding that men and women make a peculiar use of self-tracking tools, showing interest in different parameters tracked by the device (Rocket Fuel, 2014; Antezana, Venning, Smith, & Bidargaddi, 2022). The fact that women were more impacted by the bracelet with respect to men can also be interpreted by referring to the psychological literature, which acknowledges gender differences in the perception of internal signals (e.g., Vaitl, 1996). The beginning of the menstrual cycle is a psychological and physiological milestone in a woman's life (Swenson & Havens, 1987), capable of shaping the relationship with the body (Comerci, 1982). Starting from menarche, women are exposed to various internal signals that attract their attention and stimulate meaning-making processes (e.g., during pre-menopause, Ciolfi Felice et al., 2021). Uncertainty around the significance of certain bodily signals, not necessarily linked to the menstrual cycle, has been shown to trigger a reflective process in women, as it happens at the beginning of the climacteric or during menopause (Bardzell et al., 2019; Dillaway, 2020). In fact, during the interviews we conducted, we found that women gave more examples of how the Fitbit was meaningful for their experience of body-related feelings, compared to male individuals.

Given this close relationship between women and their bodies, it is likely that women would be particularly interested in consulting the Fitbit and using the data provided to better understand body-related events. The ability of the tracker to stimulate awareness can be linked to women's greater interest in monitoring their physiological sensations and is congruent with previous studies indicating gender differences in interoception (e.g., Fiskum et al., 2023; Grabauskaitė et al., 2017). The use of technological tools at their disposal, such as the Fitbit, may thus enhance this process. In fact, the Fitbit market appears to be dominated by female customers (Pew Research Center, 2020). However, prior literature shows that this support could also have detrimental effects: in the study conducted by Homewood (2020), when an app monitoring the menstrual cycle was deliberately removed in a group of women who were using it, some of them reported losing certainty and control over their own bodies, accompanied by a difficulty in explaining certain sensations and even preventing them from validating their emotions or reflecting on their behaviors, as they could not be sure whether these were influenced by biological processes (e.g., a spike in their hormones).

5.2. Self-tracking, body surveillance and body image

This study offers a psychological perspective on objectification and surveillance, which have been generally investigated by sociology researchers (e.g., Ruckenstein & Schüll, 2017; Lupton, 2014), by examining the psychological effects of using a popular self-tracking device. We found that participants in the experimental condition did not experience increased thoughts of their bodies as "social objects" (i.e., public consciousness) and were not more aware of the appearance of their body than they would normally be. Moreover, participants did not exhibit any significant difference in monitoring behaviors (i.e., body surveillance) compared to the control group, suggesting that they were unaffected by the phenomenon of body objectification, that is, an excessive concern about one's appearance or comparisons to others.

Moreover, participants' subjective feedback collected in the qualitative study clarified why the Fitbit did not have an impact on their body images, as highlighted by quantitative results. The implicit rules built into the device, which enforce certain health standards (Ajana, 2017; Sanders, 2016), left the participants feeling that Fitbit data were not representative of their body or their experiences. Therefore, the standardized and limited representations of the body offered by the Fitbit did not align with the perception of the participants, who could not recontextualize their data into meaningful narratives about themselves. Similarly, in Presset et al. (2020), some participants who used a step counting mobile application aimed at increasing physical activity complained that the device ignored their life circumstances, narrowing them down to a category (e.g., as a lazy or unhealthy person).

Perhaps because numerical data did not reflect their body image, participants also exhibited a dismissing attitude towards the *ownership* of their data, having little interest in sharing them or no worries about third party access. This mirrors and extends previous research on privacy in self-tracking that concluded that self-trackers may be willing to sacrifice their privacy if they believe that they will benefit from it (Zimmer et al., 2018). As recently found by Velykoivanenko et al. (2021), Fitbit users may fail to understand potential threats brought by disclosing physiological data collected by their tracker and underestimate the risks surrounding these devices (e.g., unwanted leakage of personal data).

However, our findings did not confirm previous research showing that self-tracking tools may worsen one's body image (Edwards, 2017; Eikey & Reddy, 2017; Honary et al., 2019) by increasing self-consciousness about appearance. However, the difference may be also due to the exclusion from our sample of people currently having serious body image concerns, as in the case of eating disorders. People with high sensitivity regarding their own bodies are prone to ruminate, that is, they excessively reflect on their own bodies and compare themselves to "ideal" standards (Dondzilo et al., 2017). Therefore, they might be more prone to ruminate after checking the Fitbit, which clearly offers a benchmark (e.g., that they did not exercise enough during the day, or that their calorie intake was excessive).

5.3. Wearable trackers as emotion-regulation tools

The consultation of the Fitbit frequently took place in response to bodily sensations that were being experienced, particularly negative ones, which were interpreted and used for action. This is not surprising, since searching for explanations does not happen when "visceral organs remain silent" and therefore there is no particular reason to pay attention to the body (Vaitl, 1996, p. 2). Individuals often attempt to exert control over uncertain and irregular sensations (Homewood, 2020; Lupton, 2016b) or when they have a health condition (Andersen & Whyte, 2014).

Several participants consulted the Fitbit in various scenarios, such as during sporting activities where a match between the displayed data and personal sensations was seen as a confirmation of their interoceptive accuracy, while mismatches provided opportunities for learning new information about one's own body. However, when unexpected sensations arose, different scenarios unfolded. When the unexpected stimulus pertained to sleep or fatigue, the correspondence of the data collected by the device with the participants' sensations sparked reflection (as in Thudt et al., 2018) helping them find a plausible explanation for their state or reinforcing their idea of having a high level of body awareness. When the data did not match the participants' perceptions, it also triggered reflection, or was dismissed as inaccurate, but in no case did it become a matter of concern. In the case of unusual heart-related stimuli, negative feelings validated by the data (e.g., an accelerated heart rate) could heighten the emotional states of participants, leading to frantically checking until the pulse rate returned to normal. Mismatches between negative feelings (e.g., increased heart rate) and the tracker feedback (e.g., displaying a regular value) could immediately soothe any concerns. This peculiar reaction may be due to the relevance of cardiac signals for survival compared to less critical stimuli like sleep quality or fatigue.

In this sense, our study expands previous research by examining how users make sense of personal data when they align or differ from their perceptions (for a review, see Coşkun & Karahanoğlu, 2022) and strengthens the notion that personal data collected by trackers has emotional implications for their users (as stated by Figueiredo et al., 2017). Mismatches can generate frustration or even anxiety (Hortensius et al., 2012), but they can also be beneficial (Thudt et al., 2018). The Predictive Processing Coding model of interoception (e.g., Apps & Tsakiris, 2014; Seth et al., 2012), which posits that the brain constantly simulates past and future body states, helps explain these phenomena. As Farb et al. (2015) pointed out, interoceptive awareness is a process that balances immediate bodily sensations with predictions of expected states based on prior experience. When unexpected interoceptive events occur (e.g., headache, hunger cramps), they are considered "prediction errors" that must be regulated to restore body balance. Instead of trying to eliminate the sensation, individuals may adjust their expectations to better align with their internal state (Farb et al., 2015). In other words, this discrepancy can be resolved by reflecting on the sensation.

In this sense, we found that emotional and behavioral responses to the Fitbit data depend on several factors: the probability of the stimulus (*is it expected?*), its quality (*is it worrying/disturbing?*) and its nature (*is it life-threatening*?). Participants aimed to minimize the discrepancies between expected and current states of the body by relying on the allegedly objective information provided by the tracker. They sometimes used this information to initiate an inference process about unexpected feelings. Cognitive reappraisal occurred when unexpected bodily states were attributed to specific reasons, thus reducing their threatening value. For instance, a sense of extreme fatigue could be explained by a low sleep quality. However, potentially life-threatening stimuli such as cardiac events were more difficult to reflect upon and prompted a state of alert. Participants struggled to disengage from the data and to regain a sense of "familiarity" that was momentarily interrupted by the bodily event. These findings may have implications for the use of activity trackers by the general population. The use of devices like the Fitbit is common in workplaces, where they are integrated into wellness programs to reduce sedentary behaviors (Pina et al., 2012) or offered as financial benefits to employees who share their health data (Chung et al., 2017). However, the use of this and similar trackers might not suit every situation or everyone, as it can disturb one's healthy relationship with the body. Given the negative consequences on people's emotions when these devices are believed to prompt potentially harmful bodily sensations, there are potential issues around their usage by people who already struggle with illness anxiety disorder, who have heightened bodily sensations and significant health concerns, and cannot be easily reassured (APA, 2014). These individuals might be easily alarmed by any feedback offered by the tracker. Moreover, they might be prompted to repeatedly check their parameters, thus worsening the performance of maladaptive health-related behaviors.

6. Suggestions for design

The aim of this section is to provide, on the basis of the study findings, several recommendations for designing self-tracking wearable devices. To start with, it is evident that the standardized metrics and benchmarks provided by devices like the Fitbit often fail to align with individual perceptions of body and health. To address this problem, future designs should consider integrating more personalized benchmarks and goals based on user's feedback, activity levels, and other personal data, as well as more personalized visualizations that align with the users' unique ways of representing their own body. Abstract data representations, like numbers and graphs, could be complemented with more "metaphorical" representations, which users can choose or even customize, in order to reflect their idiosyncratic body images.

Secondly, the study highlights how certain feedback, especially those related to vital functions such as the heart rate, could elicit strong emotional reactions in users. Moreover, data in isolation can be misinterpreted. It follows that such technologies should be designed to prevent misinterpretations of data that could alarm the user. Future designs should therefore incorporate "emotion-aware" features that can either temper potentially alarming data or provide context to help users interpret such data without undue concerns. A possible design solution to support "correct" data interpretations would be to encourage the user to provide self-reports on her emotions, activities, or particular events occurring when unusual data are collected, such as a peak in the heartbeat. The user could be asked questions like "How do you feel, right now?" or "What are you doing?" or "Is anything particular happening right now?" and the device could collect the answers. Then, when physiological data are consulted again, the tracker could display them paired with these subjective reports. This would help the user better recollect the context in which such variations in their bodily signals were captured by the tracker, assisting in interpreting unexpected sensations. Moreover, future designs could integrate more sophisticated algorithms that provide tailored advice or interventions. The device could learn how certain events relate to users' somatic sensations and provide guidance, for instance, by suggesting that the user takes a break from work, or does relaxation exercises, in order to prevent their occurrence.

That said, we believe that not all users will benefit from continuous tracking. For those with conditions like anxiety disorder, constant monitoring might exacerbate their concerns. Designers should provide options to create profiles that allow for the adjustment of the feedback and monitoring frequencies for such users. For instance, they could get less frequent updates or alerts. These users may also benefit from community support, especially when dealing with health challenges. Incorporating community features, like support groups within the tracker's ecosystem, could offer users the chance to share experiences, seek advice, or simply connect with others on similar journeys.

7. Limitations

No adverse effects concerning the objectification of the body were observed after using the Fitbit for a period of 4 months among the participants. However, it is important to interpret these results with caution, as they might also be attributed to the limited set of questionnaires and scales that were administered, which may have failed to capture the complexity of the phenomena pertaining to the body. A limitation of this study is the absence of randomization. To mitigate this, we employed a Difference-in-Difference technique for data analysis, a well-known method when randomization is not feasible (Wing et al., 2018). Another limitation is that using a specific model of the Fitbit (the Fitbit Inspire HR) may limit the generalizability of our findings, which could be different depending on the device's design characteristics. However, many of the fundamental user experiences and behaviors associated with tracking personal metrics, such as steps and heart rate, are likely to be consistent across various brands and models: in fact, previous research has highlighted that differences in usage patterns of self-tracking devices are due more to the user's "profile" (e.g., novice or expert trackers, like in Rapp & Cena, 2016; or Rapp & Tirabeni, 2018) than to the device's characteristics; moreover, the goal of our research was to explore the psychological and behavioral ramifications of self-tracking, which we believe transcend specific device features to some extent. Moreover, the limited time frame of the experiment might have affected the possibility to observe further and deeper changes. The analysis does not account for individual variations in the impact of the Fitbit on participants based on their level of interaction with the device nor does it control for any other characteristic than age (with gender not being a control variable, strictly speaking). Other limitations arise also from the characteristics of the sample, which was quite homogeneous, being composed of students of similar age and living in the same country. This potentially hinders the generalizability of the study. Finally, we did not collect details of the interviewed participants (such as their physical activity habits) which could provide additional insights. However, to maintain focus on the primary research questions, we streamlined the data collection process.

8. Conclusion

This study aimed to provide clarity on the impact of commercial wearable activity trackers on the individuals' relationship with their own bodies. We examined whether and to what extent these devices influence body awareness and representations, as well as whether the impact is positive or detrimental.

Our findings indicate that the Fitbit did not significantly affect participants' overall representations of their bodies. However, it did play a positive role in enhancing the awareness of body sensations in several ways. Firstly, it provided explanations about how the human body (and one's own body) functions. Secondly, it reassured individuals about their physical and bodily states, particularly regarding discomfort sensations. Lastly, it reinforced a positive self-perception of one's own health. Women and individuals with common physical issues such as migraine, anemia, and asthma, showed particular receptiveness to this technology.

Nevertheless, we also observed some detrimental effects. The Fitbit runs the risk of conveying standardized body images that may not align with the individuals' personal perceptions. Moreover, the sense-making process of the collected data can yield different outcomes depending on the nature of the stimuli: for instance, cardiac data may trigger alarm if they confirm an individual's negative sensations.

A major strength of this study is the methodological perspective adopted. We introduced a psychological angle to wearable tracking, offering a richer understanding to this practice. The use of both qualitative and quantitative methodologies further strengthens our study. The quantitative approach lent rigor and statistical validation to our findings, ensuring that our conclusions were empirically grounded; while the qualitative feedback provided by participants allowed us to find explanations to the quantitative data. Moreover, our findings have broad applicability as they are anchored in a widely used device. Future studies could consider more participant characteristics, trying to explore the device effect in relation to individual differences. Moreover, they could delve into the level of engagement with the wearable device, collecting data on individuals who regularly check the collected information and utilize the various functions provided by the device in comparison to those who are less actively involved.

In conclusion, our findings pave the way for future research focused on refining the design of wearable activity trackers. Future studies on self-tracking should also focus on understanding how to better support data sense-making through personalized designs and, ultimately, how to safeguard users from the detrimental consequences of misinterpreting data. As the wearable industry evolves, it becomes crucial to ensure that technologies prioritize user well-being over standardization. Our findings suggest that trackers like the Fitbit can be invaluable for individuals without access to other resources, such as medical guidance or effective coping mechanisms. Yet, it is crucial to note that such devices should not be one-size-fits-all solutions.

CRediT authorship contribution statement

Arianna Boldi: Conceptualization, Methodology, Validation, Formal analysis, Data curation, Investigation, Writing – original draft, Writing – review & editing. **Alessandro Silacci:** Formal analysis, Writing – review & editing. **Marc-Olivier Boldi:** Methodology, Formal analysis, Data curation, Writing – original draft, Writing – review & editing. **Mauro Cherubini:** Funding acquisition, Conceptualization, Writing - review & editing. **Maurizio Caon:** Writing – review & editing. **Noé Zufferey:** Data curation. **Kévin Huguenin:** Funding acquisition, Writing – review & editing. **Amon Rapp:** Conceptualization, Formal analysis, Writing – original draft, Writing – review & editing, Supervision.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: Kévin Huguenin reports financial support was provided by Swiss National Science Foundation. Kévin Huguenin reports financial support was provided by Swiss Federal Office for Defence Procurement Science and Technology.

Data availability

The data used in this study is stored in an OSF repository, which is accessible to anyone with the link. The link to the repository is provided within the paper, allowing reviewers to access it.

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