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# Physical activity improves body image of sedentary adults. Exploring the roles of interoception and affective response

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## Abstract

To reduce the number of sedentary people, an improved understanding of effects of exercise in this specific group is needed. The present project investigates the impact of regular aerobic exercise uptake on body image, and how this effect is associated with differences in interoceptive abilities and affective response to exercise. Participants were 29 sedentary adults who underwent a 12-week aerobic physical activity intervention comprised of 30–36 sessions. Body image was improved with large effect sizes. Correlations were observed between affective response to physical activity and body image improvement, but not with interoceptive abilities. Explorative mediation models suggest a neglectable role of a priori interoceptive abilities. Instead, body image improvement was achieved when positive valence was assigned to interoceptive cues experienced during exercise.

**Keywords** Physical activity · Body image · Interoception · Affective response

Decreasing the number of inactive people could avert significant proportions of the major non-communicable diseases and significantly increase life expectancy (Lee et al., 2012). Interestingly, although engagement in physical activity is associated with a variety of physiological as well as psychological aspects of health and well-being (Posadzki et al., 2020; Thomas et al., 2020), the number of regular exercisers stagnates (Du et al., 2019). The present project contributes to understanding individual barriers and motivation for exercise by exploring how a 12-week aerobic exercise intervention impacts body image in sedentary individuals and what potential underlying mechanisms might be.

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Improving satisfaction with one’s body contributes to efficient weight management, and is a key motivation for physical activity uptake (Allender et al., 2006; Bray et al., 2016; Kim, 2021). Indeed, systematic reviews suggest that regardless of actual improvement in fitness level and body mass index (BMI), body image can be improved via participation in physical activity alone (Alleva et al., 2015; Campbell & Hausenblas, 2009; Srismith et al., 2020). However, the reviewed effects were found within samples of volunteered participants, which means that a selection bias for participants with generally positive attitudes towards physical activity is likely. This is problematic because exercise doesn’t universally make everyone “feel better”. Specifically, for sedentary people, a better understanding of what happens in the short and long term after they begin physical activity could spare them frustrating experiences and improve their success rate in becoming more active.

Behavioral theories of physical activity assign a key role to the affective response to exercise, i.e., that the positive or negative affect induced by exercise influences the future adherence through learned associations (Rhodes & Kates, 2015). Two main factors have been suggested to determine such affective response: (a) cognitions on the meaning of exercise, self-perceptions or goals and (b) processing of the interoceptive signals induced by exercise (Ekkekakis, 2009).

While the overall association between affective response to exercise and adherence is well documented (Rhodes & Kates, 2015), the detailed mechanisms, and specifically the role of interoception, still remain unclear. In this study, we therefore explore the effects of different aspects of interoception on the affective response to physical activity and on body image outcomes.

Interoception is often used as a vague construct referring to the inner state of the body. However, it is a highly differentiated construct with close conceptual and anatomical links to affective processing and body image. Interoception refers to the perception and processing of the bodily state, encompassing afferent information from the viscera (including heart beat), anatomical position, and body temperature (Craig, 2009; Tsakiris & Critchley, 2016). Most experimental paradigms that assess interoception focus on heartbeat, while paradigms that address other bodily states such as filling levels/distensions of the stomach or bladder are used more rarely (Garfinkel et al., 2015). Generally, three different outcomes are distinguished: (1) interoceptive accuracy, which refers to the performance in detecting one's heartbeat, (2) interoceptive sensitivity, which refers to the self-report of experiencing interoceptive signals, and (3) interoceptive awareness, i.e. the correspondence between subjective self-report and objective performance (Garfinkel et al., 2015). Consistent with the Schachter-Singer theory of emotion (Critchley & Garfinkel, 2017; Schachter & Singer, 1962), a recent literature review (Wallman-Jones et al., 2021) suggests that physical activity triggers a cascade of physiological processes whose processing is closely linked to the cognitive evaluation of the activity. Wallman-Jones et al. (2021) suggest that repeated processing of physical changes induced by physical activity triggers long-term changes in interoceptive abilities and general self-awareness.

Current literature on the association between interoceptive abilities and body image, i.e. the cognitions and attitudes that persons hold towards their body, is mostly cross-sectional and suggests that better interoceptive abilities (mostly operationalized as either interoceptive accuracy or interoceptive sensitivity) are associated with a more positive body image (Badoud & Tsakiris, 2017). This finding implies questions about the specific role of interoception for uptake of physical activity. For example, it could mean that good interoceptive perception is a prerequisite for experiencing and attributing positive affects to physical activity. Alternatively, it could reflect the importance of capabilities in finding an appropriate level of physical activity in the sense that successful exercisers have good insights into their physical needs. Lastly, it could also reflect typical attentional mindset in regular exercisers. In either case, known mechanisms would allow for more targeted training plans based on baseline interoception assessments (Clement & Löwe, 1996b).

In this study, a sample of sedentary individuals was followed up over the course of a 12-week ergometer-based training intervention. Unlike previous studies, we focused on investigating individuals who were not able or willing to maintain regular physical activity in the past, and supported them in initializing regular aerobic exercise over a significant time period. We investigated three study questions:

(1) Can sedentary peopleimprove their body image through physical activity? Consistent with previous studies, we hypothesized that physical activity uptake leads to an improvement in body image.

(2) Are changes in body image predicted by baseline interoceptive abilities? Extrapolating from the existing interoceptive and behavioral literature, we expected that higher interoceptive accuracy and awareness, as well as a more positive evaluation of interoceptive cues, would be significantly associated with better body image outcomes.

(3) Are associations between different aspects of interoception and body image outcomes mediated through affective response to physical activity? For this study question, we distinguished different aspects of interoception and affective response and explored three mutually exclusive mediation models of how the three constructs might be associated: (A) a *perception model* hypothesizing that individuals who are better at perceiving interoceptive cues (thereby scoring higher in *interoceptive accuracy*) may experience and report higher activation during physical activity (*FAS*), and report higher changes in perception of their own body dynamics, as operationalized through *BIQ-20 Perception of Body Dynamics*; (B) a *cognition* model, *where interoceptive awareness* of participants' own interoceptive accuracy predicts *affective valence* rating during physical activity as a mediator for changes in *BIQ-20 Negative Evaluation of the Body*; and (C) a *valence* model, where individual differences in *interoceptive sensitivity* predict changes in the perception of body dynamics (*BIQ-20*), mediated by *affective valence* rating during physical activity.

## Method

### Participants

Twenty-nine healthy participants ($M_{age} = 27.07$, $SD = 5.62$; 69% female) who took part in the iReAct project (Thiel et al., 2020) were examined in this study. The iReAct project is designed as an interdisciplinary research network investigating physiological, affective, and cognitive responses to high intensity interval training (HIIT) versus moderate intensity continuous training (MICT), both conducted as ergometer training over a period of 12 weeks. The study was approved by the ethics committee of the university of Tübingen, Germany, (No.:882/2017BO1) and was registered at the German Clinical Trials Register (No.:DRKS00017446, available at https://www.drks.de). Informed consent was obtained at the point of recruitment.

All participants reported insufficient engagement in physical activity at the time of recruitment (i.e., less than 150min/week of physical activity; less than 60min/week of physical activity during leisure time; no regular engagement in physical activity during the last six months; maximum oxygen uptake (VO2max) between 25 and 50 ml/min/kg). Participants were medically examined and ensured to be in good health (e.g., no current or history of eating disorder, obesity, or neurological illness; no current psychotherapy; BMI between 18,5 and 30,0kg/m2; no history of drug use or alcohol abuse; non-smokers; not currently pregnant or in a breastfeeding period; no medication or supplement intake within the last 4 weeks that might interfere with study results; normal lab results for blood sample).

## Materials and procedure

### General procedure

After study inclusion as well as after each training block, all participants underwent diagnostic sessions as well as a reference training session. A comprehensive list of assessments is provided in the study protocol (Thiel et al., 2020). For this study, we analyzed baseline and post-training measures for interoceptive accuracy, interoceptive awareness and body image, as well as affective response to the reference training and evaluation of interoceptive cues during the reference training sessions which took place pre-training intervention.

All participants underwent 6 weeks of ergometer HIIT as well as another 6 weeks of ergometer MICT in randomized order. The training order was counterbalanced across participants. The HIIT sessions took 43min and consisted of a 10-minute warm-up at a power output corresponding to 70% of the individual maximal heartrate, followed by four 4-minute intervals at a power output corresponding to 90% of the maximum heart rate with 4-minute resting periods at 30W between each interval. After the last interval, a cool-down period was performed for 5min at 30W. MICT, in contrast, consisted of 60min continuous cycling at a power output of 90% of the first lactate threshold. There was no washout period between the two training regimes. All training sessions were performed on calibrated cycling ergometers. Supervision was provided for all training sessions. Participants completed a minimum of 30 (of the total 36) training sessions within the 12 weeks of intervention. It must be noted that the group comparison between training types and order (i.e., MICT-HIIT versus HIIT-MICT) is not relevant for the current work but reported elsewhere (Mattioni Maturana, 2021, for training type comparison). The focus here is on the fact that all subjects successfully underwent regular physical training over a period of 12 weeks.

### Assessment of interoception

Interoceptive accuracy and interoceptive awareness were assessed using a heartbeat tracking task and heartbeat discrimination task in accordance with the experimental paradigm described in Garfinkel et al. (2015). Since these procedures assess interoception only in a resting condition, we additionally assessed the evaluation of interoceptive cues immediately after the reference training session.

**Interoceptive accuracy and interoceptive awareness.** For the experimental assessment, a pulse oximeter was attached to participants' non-dominant index finger ('soft' mount PureLight sensor; Nonin Medical Inc., MN, USA) and they were instructed to rest both hands on the table in front of them. For the heartbeat tracking task, participants were instructed to "silently count the number of heartbeats you feel from the time you hear 'start' to when you hear 'stop'". Six trials of varying duration (i.e., 25, 30, 35, 40, 45, 50s) were implemented in a randomized order. The number of counted heartbeats was verbally reported and noted by the experimenter at the end of each trial. Participants were not given any feedback on their performance accuracy.

For the heartbeat discrimination task, participants were instructed: "You will hear ten auditory tones. Please tell me if the tones are in sync or out of sync with your own heartbeat." Twenty trials (10 synchronous, 10 asynchronous in randomized order) were conducted. Tones were presented at 440Hz for 100ms. Participants' answers were recorded by the experimenter before proceeding to the next trial. No feedback on participants' performance was given.

For both heartbeat detection tasks, immediately following each trial, participants were asked to give a *confidence* rating of their answer using a pencil on a 10cm VAS, which ranged from 'total guess/no heartbeat awareness' to 'complete confidence/full perception of heartbeat'.

The *interoceptive accuracy* score of the heartbeat tracking task was derived for each trial: $1 - (|n\text{beats}_{real} - n\text{beats}_{reported}|)/((n\text{beats}_{real} + n\text{beats}_{reported})/2)$. Resulting accuracy scores were averaged over the 6 trials, yielding an average accuracy score for each participant (Garfinkel et al., 2015; Hart et al. 2013). For the heartbeat discrimination task, *interoceptive accuracy* was calculated as the ratio of correct to incorrect synchronicity judgements (range: 0 to 1).

*Interoceptive awareness* score, reflecting metacognitive insight into participants' performance, was calculated for the heartbeat tracking task using the within-participant Pearson correlation, *r*, between *interoceptive accuracy* and *confidence* rating for each trial. Interoceptive awareness for heartbeat discrimination task was quantified using receiver operating characteristic (ROC) curve analysis (Green & Swets, 1966) of the extent to which confidence predicted accuracy. Specifically, of the trial-by-trial correspondence between *accuracy* (correct/incorrect synchronicity judgement) and *confidence* rating (Garfinkel et al., 2015).

**Evaluation of interoceptive cues.** Immediately after completion of the reference training session, participants were asked to indicate their *evaluation of interoceptive cues*. For the reference training session, participants performed continuous cycling exercise consisting of a 10-minute warm-up period at a power output corresponding to 90% of the first lactate threshold, followed by a 50-minute period of constant load corresponding to the midpoint between the first and the second lactate threshold.

Using a smartphone (Google Nexus 5; LG, Seoul, South Korea), with the application "movisensXS" (movisens GmbH, Karlsruhe, Germany), participants were asked to "indicate below how the following aspects have influenced your overall well-being during the training" and to complete the statement: "My physical reactions and sensations were…" on a visual analogue scale (VAS) via a sliding controller. This is an in-house designed, non-validated, single-item questionnaire based on procedures by Rose and Parfitt (2010). Three values on the scale were assigned modifiers: 0 as 'very disturbing', 50 as 'neutral', and 100 as 'very beneficial'. Participants were able to freely move the slider and submit their answer at any position on the scale.

#### Assessment of affective response to physical activity

Four facets of individuals' affective response to physical activity were measured at pre and post, as well as throughout the baseline reference training session: affective valence, perceived activation, exercise enjoyment, and exercise avoidance.

**Perceived activation and affective valence.** Using the same smartphone setup as the one used to assess *evaluation of interoceptive cues*, participants' in-situ affective responses to physical activity were measured according to the circumplex model (Russell, 1980). *Affective valence* and *perceived activation* were measured at 7 different timepoints throughout the entire reference training session: at minutes 0 (pre-training), 10, 20, 30, 40, 50, 60 (post-training). Data obtained immediately post-training (minute 60) were used in the analysis.

*Affective valence* was assessed using the German version of the Feeling Scale (FS; Hardy & Rejeski, 1989; Maibach et al., 2020), where participants were prompted to rate their current feelings on an 11-point bipolar scale ranging from: +5 'very good', through 0 'neutral', to -5 'very bad'. *Perceived activation* was assessed using the German translation of the Felt Arousal Scale (FAS; Maibach et al., 2020; Svebak & Murgatrovd, 1985), where participants were prompted to rate their current level of arousal on a 6-point scale, ranging from 1 'low arousal' to 6 'high arousal'.

**Exercise enjoyment and exercise avoidance.** The single-item Exercise Enjoyment Scale (EES; Stanley & Cumming, 2010) was adapted to assess participants' *enjoyment* immediately after completion of the reference training session. On the same smartphone set-up, participants used a VAS (with values ranging from 0 to 100) respond to the following item: "Indicate here how much you enjoyed the physical activity."

According to the EES, another single-item measure was created to determine participants' degree of *avoidance*. Participants used the same VAS to give their response to the following statement: "Indicate here how much you have experienced unpleasant experiences/feelings during the physical activity."

#### Assessment of body image

Body image scores were assessed at both baseline and follow-up (i.e., before starting & upon completion of the intervention) using the German version of the Body Image Questionnaire (*BIQ-20*; Clement & Löwe, 1996b). For the present analysis, the change scores (the difference between pre and post-intervention scores) were used. The BIQ-20 comprises of 20 items and assesses body image on two independent sub-scales: *Perception of Body Dynamics (PBD)* and *Negative Evaluation of the Body (NEB)*. The *BIQ-20* was selected to measure body image outcomes in this current study due to its two-dimensional score from the two sub-scales. An individual's attitude towards their own body (i.e., subjective evaluation of own appearance, feeling of bodily coherence, emotional well-being in the body; measured by *NEB*), as well as their perception of their own personal vitality (i.e., physical efficacy, perception of health, feelings of vitality, interests in bodily activities; measured by *PBD*), can be considered separately—the latter of which is especially appropriate in the context of physical activity. Several studies have proven the questionnaire's validity, reliability, sensibility, as well as specificity (Junne et al., 2019; Lamade et al., 2011; Teufel et al., 2012).

### Statistical analysis

Statistical analyses were performed in IBM SPSS Statistics version 26. To determine change in body image following the intervention, paired samples t-tests were conducted

**Table 1** Sample characteristics of participants (n = 29)

| | Mean | Standard Deviation | Range |
|---|---|---|---|
| Gender[1] | 20♀ 9♂ | — | — |
| Age (years) | 27.07 | ±5.62 | 20–40 |
| Interoceptive Accuracy (Heartbeat Tracking) | 0.65 | ±0.19 | 0.09—0.95 |
| Interoceptive Accuracy (Heartbeat Discrimination) | 0.50 | ±0.15 | 0.10—0.75 |
| Interoceptive Awareness (Heartbeat Tracking) | 0.16 | ±0.5 | -0.63—0.96 |
| Interoceptive Awareness (Heartbeat Discrimination) | 0.49 | ±0.13 | 0.25—0.72 |
| Evaluation of interoceptive Cues during RTS (0 to 100) | 56.66 | ±19.32 | 14.00—90.00 |
| Perceived Activation at Min 60 of RTS (1 to 6) | 4.34 | ±1.4 | 1.00—6.00 |
| Affective Valence at Min 60 of RTS (-5 to +5) | 1.79 | ±2.19 | -3.00—5.00 |
| Exercise Enjoyment during RTS (0 to 100) | 57.66 | ±24 | 9.00–87.00 |
| Exercise Avoidance during RTS (0 to 100) | 37.52 | ±25.87 | 0.00–82.00 |
| BIQ-20 Perception of Body Dynamics change score* | 9.38 | ±10.76 | -15.00–30.00 |
| BIQ-20 Negative Evaluation of the Body change score*,[2] | -10.00 | ±9.41 | -29.00–8.00 |

*Note.* BIQ-20: Body Image Questionnaire (Clement & Löwe, 1996); RTS: Reference Training Session. [1]The frequency of male (♂) and female (♀) subjects instead of the mean is reported; [2]Negative value indicates reduction in Negative Evaluation of the Body. *All assessments were taken at baseline except for BIQ-20 change scores, which report differences between BIQ-20 scores at baseline and follow-up

on the *BIQ-20* subscales. To assess bivariate associations between interoception, affective response to physical activity and body image change, Pearson correlations were computed.

Mediation analysis was performed according to the approach by Hayes (2018), utilising the PROCESS macro for SPSS version 3.4. Inference about the indirect effect was determined by bootstrapping, reporting 95% bootstrap confidence intervals. The number of bootstrap samples was set at 10,000. Effects of the mediation analysis are reported as unstandardised effects (*b*). If statistically possible and meaningful, combined interoception scores from different tasks were used as predictors.

# Results

## Sample characteristics

Sample characteristics of participants at pre and post-physical activity intervention are presented in Table 1. All interoceptive and affective response measures presented in Table 1 were measured at baseline. Body image outcomes are reported as change scores, which are derived from the differences between baseline and follow-up *BIQ-20* scores.

## Change in body image

*BIQ-20* scores at pre-intervention (measured at baseline) were compared to *BIQ-20* at post-intervention (measured at follow-up) for both sub-scales. There was a significant difference between baseline *BIQ-20 PBD* ($M = 25.17$, $SD = 7.90$) and follow-up scores ($M = 34.55$, $SD = 5.09$); $t(28) = -4.70$, $p < 0.001$, Hedges $g = 0{,}86$ (corrected for correlation $g = 1{,}42$). There was also a significant difference between baseline *BIQ-20 NEB* ($M = 32.07$, SD = 5.47) and follow-up scores ($M = 22.10$, $SD = 6.48$); $t(28) = 5.70$, $p < 0.001$, Hedges $g = 1{,}05$ (corrected for correlations $g = 1{,}64$).

## Correlations between interoception, affective response to the reference training and change in body image

An overview containing all correlations is provided in Table 2. Overall, accuracy and perceptive aspects of interoception are significantly linked to a number of affective response dimensions. However, there was no significant correlation between any interoceptive dimension and body image change. All dimensions of interoception investigated here were not intercorrelated, and there was no intercorrelation between perceived activation and affective valence.

## Mediation analysis

Figure 1 illustrates the results of the mediation analyses. For all models, the total effects model for interoception predicting changes in *BIQ-20*, as well as most mediation models that included aspects of affective evaluation as mediators, were not significant. Only for the cognition model using interoceptive awareness from the heartbeat tracking task as predictor and affective valence during physical activity as mediator, the mediation model was overall significant with 24% of the variance in *BIQ-20 NEB* change explained [$F(2,26) = 4.06$, $p < 0.05$, $R^2 = 0.24$]. Nevertheless, the indirect effect that depicts the influence of interoceptive awareness on *BIQ-20 NEB* change score mediated by affective valence was not significant [$b = 0.10$, 95% BCa CI (-0.05, 0.29)]. Additionally, interoceptive awareness from the heartbeat tracking task does not significantly predict *BIQ-20 NEB* change score with affective valence in the model [$b = -5.76$, $t(26) = -1.70$, $p = 0.10$]. However, affective valence significantly predicts change *BIQ-20 NEB* [$b = -1.97$, $t(26) = -2.61$, $p < 0.05$].

**Table 2** *Correlations among interoceptive dimensions, affective response to physical activity, and body image outcomes*

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. Interoceptive Accuracy (Heartbeat Tracking) | — | | | | | | | | | | |
| 2. Interoceptive Accuracy (Heartbeat Discrimination) | 0.10 | — | | | | | | | | | |
| 3. Interoceptive Awareness (Heartbeat Tracking) | −0.16 | −0.05 | — | | | | | | | | |
| 4. Interoceptive Awareness (Heartbeat Discrimination) | 0.10 | 0.28 | 0.19 | — | | | | | | | |
| 5. Evaluation of Interoceptive Cues during RTS (0 to 100) | −0.24 | 0.01 | −0.21 | −0.02 | — | | | | | | |
| 6. Perceived Activation at Min 60 of RTS (1 to 6) | **0.44*** | 0.01 | −0.10 | −0.08 | 0.15 | — | | | | | |
| 7. Affective Valence Score at Min 60 of RTS (-5 to +5) | −0.05 | −0.07 | −0.23 | −0.12 | **0.53**** | 0.13 | — | | | | |
| 8. Exercise Enjoyment during RTS (0 to 100) | −0.23 | 0.07 | −0.16 | −0.22 | **0.73**** | 0.24 | **0.44*** | — | | | |
| 9. Exercise Avoidance during RTS (0 to 100) | 0.33 | −0.01 | −0.04 | 0.13 | **−0.56**** | −0.09 | **−0.60**** | −0.45* | — | | |
| 10. Change in Perception of Body Dynamics (BIQ-20) | −0.13 | −0.16 | 0.26 | −0.14 | 0.11 | 0.00 | **−0.51**** | 0.09 | −0.36 | — | |
| 11. Change in Negative Evaluation of the Body (BIQ-20) | 0.23 | 0.08 | −0.20 | −0.02 | −0.23 | −0.09 | **−0.39*** | −0.20 | **0.37*** | −.87** | — |

*Note*. *$p < 0.05$, **$p < 0.01$, two-sided. RTS: Reference training session at baseline-Assessment; BIQ-20: Body Image Questionnaire (Clement & Löwe, 1996). All assessments were taken at baseline except for BIQ-20 change scores, which report differences between BIQ-20 scores at baseline and follow-up

A comprehensive report on the results of the mediation analyses is provided in the supplementary materials section.

## Discussion

In this study, we observed in a sample of sedentary individuals that 12 weeks of regular aerobic exercise improve body image with large effect sizes. Following existing literature, we examined the role of interoceptive processing for this effect. Interoceptive abilities at baseline were not associated with affective response to physical activity or body image outcomes. Rather, explorative analyses revealed that body image improvement is driven by affective evaluation of interoceptive cues and the overall training experience. To optimize benefits of physical activity for sedentary adults, intervention research should focus on how to provoke a positive experience of physical activity in this group.

Our current study adds on to existing research (Srismith et al., 2020) and confirms that uptake of regular aerobic exercise improves body image in sedentary individuals. This is insofar remarkable, as participants indicated a neutral attitude towards exercise in the reference training session. It can be assumed that in non-study circumstances, the affective reaction alone would not have been sufficient to promote a second session of exercise in the sense of operant conditioning. Still, our observations suggest that maintaining regular exercise induces positive effects over time. Hence, in order to support sedentary individuals in getting more active, additional incentives and support are needed for the starting period.

In this study, we used a broad set of tasks to assess interoception. Interestingly, neither interoceptive accuracy nor interoceptive awareness as assessed through the heartbeat discrimination task were associated with affective evaluation of physical activity or body image outcomes. Only interoceptive accuracy as assessed through the heartbeat tracking task correlated with perceived activation during the reference training. These observations contradict previous findings (Badoud & Tsakiris, 2017; Wallman-Jones et al., 2021), but match observations in children who underwent a complex inpatient-treatment for obesity (Mölbert et al., 2016). It is possible that due to the lack of experience with strong interoceptive signals, sedentary individuals indeed have less insight into their cardiac status and therefore rely less on this information for affective evaluations. Additional cross-sectional data and longitudinal data with longer training periods could help to better understand the role of regular physical activity on interoception.

Using mediation models, we explored several pathways through which interoception could act on body image. While previous research suggested a direct link between interoception and body image, our results suggest that, if at all, the relationship is mediated by affective evaluation of the interoceptive signals. The only mediation model that was significant involved evaluation of interoceptive cues as a predictor, i.e., to what degree participants were disturbed or felt pushed by their interoceptive perceptions. A possible explanation is a lack of variance in interoception due to our sample selection: individuals that are typically insensitive to their interoceptive signals while at rest simply cannot help but become aware of their internal bodily signals while

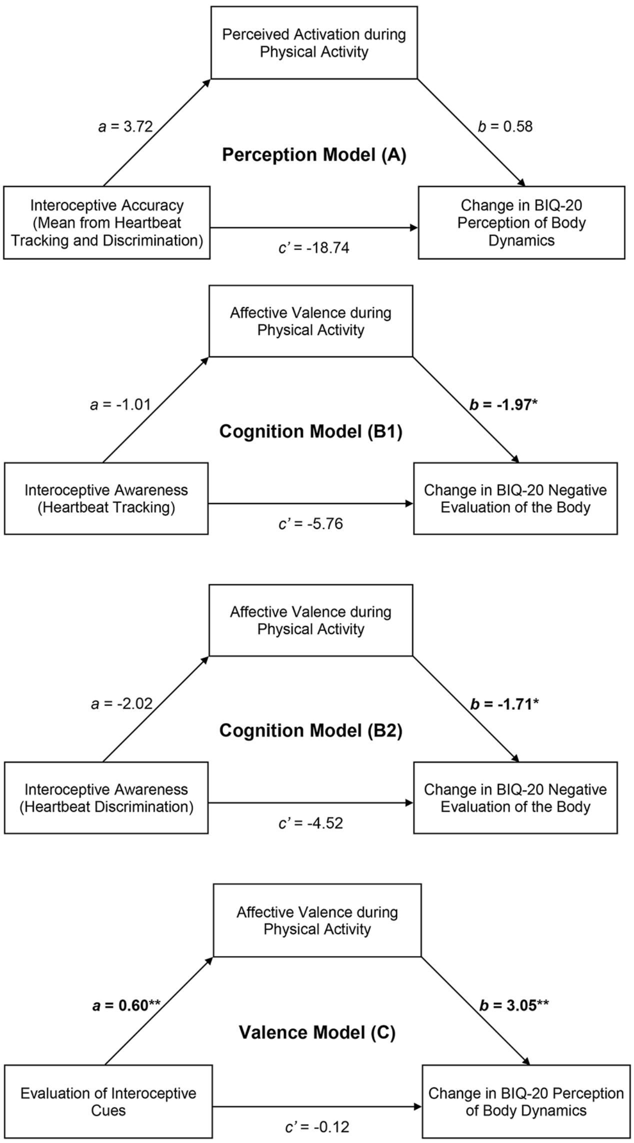


**Fig. 1** *Graphical illustrations of the mediation analyses on the proposed models concerning relationships between interoceptive dimensions, affective response to physical activity dimensions, and body image outcomes*
Note: Displayed effects are direct effects. *$p<0.05$, **$p<0.01$, two-sided

being physically active, thus rendering individual differences in interoceptive abilities obsolete. A more heterogeneous sample would be needed to trace down differential effects of interoceptive activation. However, we observed for our sedentary group that affective evaluation of the arousal induced by physical activity is crucial for the overall evaluation of the activity, as well as impacts the body image outcome. Even though this observation is based on a sharply powered data analysis, it provides first evidence on a formerly hardly investigated question and can inspire further studies.

It is a strength of this study that it employed a comprehensive approach with a longitudinal design, in which sedentary participants underwent a rigorously supervised and well-defined regular physical activity intervention. Sedentary adults who are starting regular aerobic exercise are a highly relevant, but so far insufficiently studied, subset of the healthy population. However, it must be noted that our sample size was relatively small, specifically for mediation analyses it was sharply powered (Hayes, 2018). We therefore emphasise that the results of our mediation analyses need further confirmation and consideration in samples with a more heterogenous, yet well-defined activity biography.

Behavioral theories of physical activity suggest that interoceptive processing is relevant for the formation of affective response to exercise which, in turn, determines adherence to regular exercise. Our observations suggest that in sedentary adults, a priori differences in interoceptive abilities are largely irrelevant for the affective processing. Rather, a priori differences in evaluation of strong interoceptive arousal contribute to the overall rating of the activity. This interpretation matches previous research that reported inter-individual variability in how affective response relates to exercise intensity (Acevedo et al., 1994; Ekkekakis et al., 2011). Our observations also emphasize that body image improvement through physical activity typically occur over time even though the activity is only neutrally evaluated. An application in the development of interventions for sedentary groups could be a cognitive module with the aim to prepare individuals for unusual bodily sensations during exercise, promote an open attitude towards this experience and provide information on positive processes triggered by the strong activation.

**Supplementary Information** The online version contains supplementary material available at https://doi.org/10.1007/s12144-022-03641-7.

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**Data Availability** In order to comply with the ethics approval of the study protocol, data cannot be made accessible through a public repository. Interested colleagues are invited to reach out to the authors to discuss individual solutions.

## Declarations

**Conflict of interest** The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.



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