Physical activity and fitness in patients with COPD
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CHAPTER 2

Functional and psychological variables both affect daily physical activity in COPD: a structural equations model

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ABSTRACT

Background: Daily physical activity (DPA) level is reduced in patients with COPD. The aim of this study was to investigate the association of DPA with functional and psychological variables in these patients.

Methods: 155 COPD patients (102 males, median (IQR) age 62 years (54-69 years), predicted FEV₁ 60% (40%-75%) were included. We assessed DPA (DigiWalker SW-200), functional capacity and psychological factors.

Results: DPA level was significantly associated with all functional capacity variables and two psychological variables (Perceived Physical Ability Subscale, depression subscale of the Hospital Anxiety and Depression Scale). The six-minute walking distance and Saint George Respiratory Questionnaire activity score explained 37% of the variance of DPA in a regression analysis. A structural equations model revealed that psychological variables indirectly explained DPA through functional capacity variables. DPA was stronger associated with functional capacity variables and weaker with psychological variables in patients with lower functional status than in patients with higher functional status.

Conclusions: Higher levels of DPA are associated with better functional capacity, but interestingly, DPA is also affected by psychological factors, though only indirectly, via functional capacity. The effect of specific treatment addressing psychological factors on DPA level and exercise tolerance needs further investigation. Clinical Trial Registration: ClinicalTrials.gov, NCT00614796.
INTRODUCTION

Patients with COPD may enter a vicious circle of reduced lung function, activity-induced dyspnea, immobilization, muscle deconditioning and muscle fatigue. In addition, psychosocial consequences like depression and social isolation may appear (www.goldcopd.com). This vicious circle may affect daily physical activity level (DPA) in COPD patients, assessed using accelerometers\(^1\)\(^-\)\(^6\) and pedometers\(^7\),\(^8\). Lower DPA level is related to lower FEV\(_1\)\(^1\)\(^-\)\(^3\),\(^7\),\(^8\), VO\(_2\)\(_{\text{peak}}\)\(^1\),\(^4\),\(^5\) and 6MWD\(^1\),\(^6\). In addition, a very low DPA level was associated with a higher risk for all-cause and respiratory mortality.\(^9\)\(^-\)\(^12\) The association of DPA with psychological variables such as anxiety, depression, self-efficacy and motivation has not been investigated extensively; depression was not associated with DPA level in two studies\(^6\),\(^13\), whereas self-efficacy has been shown to correlate positively with DPA\(^1\),\(^14\). In addition, DPA counseling has been shown to improve intrinsic motivation for physical activity.\(^15\)

We hypothesized that variables reflecting functional capacity as well as psychological variables influence DPA. In addition, we hypothesize that variables reflecting functional capacity affect DPA more in patients with a low functional status and psychological affect DPA more in patients with high functional status. To investigate this a broad group of COPD patients is included from the primary (general practitioner), secondary (hospital outpatient clinic) and tertiary (pulmonary rehabilitation centre) healthcare setting.

As we were interested in both direct and indirect relationships between DPA, functional and psychological variables, we performed, in contrast to previous studies\(^1\)\(^-\)\(^8\), a path analysis using the structural equations modeling (SEM) technique, which allows estimation of direct and indirect associations of groups of variables.

METHODS

Subjects

Patients with stable COPD (n=155) from seven general practices, four hospital outpatient clinics and one pulmonary rehabilitation centre were included. These patients participated in a controlled study of a physical activity counseling program. Inclusion criteria were diagnosis of COPD according to the GOLD criteria\(^16\) and age between 40 and 80 years. Exclusion criteria were significant comorbidities interfering with physical activity and exacerbation or respiratory tract infection in the past two months. All patients signed a written informed consent. The study was approved by the local medical ethics committee of the University Medical Center Groningen (METc2006/143) and registered in ClinicalTrials.gov: NCT00614796.

Measurements

Performance-based daily physical activity

Performance-based DPA (steps/day) was measured with the Digiwalker SW-200 pedometer (Yamax; Tokyo, Japan), which is an accurate measurement tool to detect steps taken.\(^17\)\(^-\)\(^20\) Patients were instructed to wear the pedometer during two weeks (from waking up until going to bed) and to record the number of steps per day in a diary. The mean of the last week of steps was used for further analyses. Data from this week were only used when more than 5 days of 7 were filled out.
Physiological characteristics
Weight, height and fat-free mass were measured, the latter by a bioelectrical impedance analysis (Bodystat 1500).21

Functional Capacity
Performance-based functional capacity was assessed by lung function using a spirometer (Jaeger MS-IOS) and bodyplethysmograph (Masterlab version 4.52i) according to standardized guidelines.22 Reference values used were those of the European Community for Coal and Steel.22 The six minute walking distance (6MWD) was used to assess functional exercise capacity and was performed in accordance with international standards.23

Self-reported functional capacity was assessed by multiple questionnaires. Independent functioning in daily living was assessed by the Groningen Activity Restriction Scale (GARS).24 Disease specific health-related quality of life was assessed by the St. George Respiratory Questionnaire (SGRQ).25 The domains of this questionnaire containing items about functional capacity (activity and impacts scales) were selected for further analysis. Health status was assessed by the Short Form 36 (SF-36) (general) and Clinical COPD Questionnaire (CCQ) (disease specific).26,27 The physical functioning scale (SF-36) and functional status scale (CCQ) were used for further analysis. Fatigue due to daily activities in household, body care and social activities were measured with the Dutch Exertion and Fatigue Scale (DEFS).28

Psychological capacity
Anxiety and depression were measured with the Hospital Anxiety and Depression Scale (HADS).29 Self-efficacy was measured by the Perceived Physical Ability Subscale (PPAS) of the physical self-efficacy scale.30 The level of intrinsic motivation for physical activity was measured using the Self-Regulation Questionnaire for Exercise (SRQ-E). This questionnaire deals with the reason why a person engages in physical activities and is based on the format of Ryan and Connell.31

Statistical analysis
Univariate and multivariate analysis
Because of non-normal distribution of the primary outcome measure steps/day, Spearman's correlations of DPA with psychological and functional variables were calculated in the total group and in 2 subgroups based on functional status measured by the 6MWD (split by the median of 6MWD).

Multiple linear regression models (method stepwise) were constructed including 1) all variables (functional and psychological) that correlated significantly with steps/day, and 2) only psychological variables (anxiety, depression, self-efficacy and motivation). These statistical analyses were performed using Scientific Package of Social Sciences (SPSS) version 18.0. To test the null hypothesis alpha was set at 0.05.

Structural equations model
A path analysis (LISREL 8.7) was used to test the hypothesized model, in which the direct effects of functional variables on DPA and simultaneously the indirect effects of psychological variables on DPA mediated through functional variables were estimated. In this model latent
constructs were conceptualized by ‘DPA’, ‘functional capacity’ and ‘psychological capacity’. DPA was a latent construct estimated by taking the natural logarithm of steps/day. Indicators of the latent construct ‘functional capacity’ were performance-based (FEV₁, 6MWD) and self-reported (GARS, SGRQ activity and impacts, SF36 physical functioning, CCQ functional and DEFS) functional capacity. The latent construct ‘psychological capacity’ was indicated by HADS anxiety, HADS depression, SRQ-E and PPAS.

Variables were chosen based on their significant correlation with DPA in the univariate analysis or because they were thought to be interesting from a theoretical point of view. Of the lung function variables only FEV₁ was used, and not RV%TLC because both variables were highly associated with each other, but FEV₁ had a higher correlation with DPA. To allow for mutual comparisons between path coefficients, the completely standardized solution was used. For model fit we used multiple criteria as suggested by Bentler and Bonett. The first criterion used for model fit is a non-significant χ² indicating that a non-significant amount of variance in the data remains unexplained. However, a statistically significant χ² can often be produced as an artifact of sample size and of small variations in the data. The second criterion is the ratio of χ² to the degree of freedom, a ratio ranging from 2 to 5 has been recommended as acceptable for good model fit. The last criterion used is the root mean square error of approximation (RMSEA), which assesses how well the model approximates the data by determining the lack of fit of the model to the population covariance matrix, expressed as the discrepancy per degree of freedom. An RMSEA with values of less than 0.05 indicates a good fit to the data although values up to 0.08 are acceptable as well. However, values greater than 0.10 strongly suggest an unsatisfactory model fit.
RESULTS

Data from 155 patients with COPD from GOLD stage I (n=32), II (n=65), III (n=38) and IV (n=20) were used for all analyses. The median (IQR) DPA level for the total group was 4206 (2387-6284) steps/day (Table 1). Baseline scores of the questionnaires are shown in Table 2.

Table 1. Baseline characteristics (n=155)

| Clinical characteristics                              |       |
|-------------------------------------------------------|-------|
| Age, y                                                | 62 (54-69) |
| Gender, m/f                                           | 102/53 |
| Healthcare setting, GP/outpatient cl./PR (n)          | 48/46/61 |
| Medication (n)                                        |       |
| Short acting beta agonist                             | 43    |
| Short acting muscarinic antagonist                     | 35    |
| Long acting beta agonist                              | 21    |
| Long acting muscarinic antagonist                      | 83    |
| ICS                                                   | 32    |
| Combination (ICS + long acting beta agonist)          | 99    |
| Pack years                                            | 33 (17-50) |
| BMI, kg/m$^2$                                         | 26.1 (22.8-29.0) |
| FFMI, kg/m$^2$                                        | 17.4 (16.1-18.9) |
| FEV$_1$,% pred                                        | 60 (40-75) |
| FEV$_1$,%FVC, %                                       | 45 (34-59) |
| RV%TLC, %                                             | 47 (41-54) |
| 6MWD, m                                               | 452 (360-515) |
| **DPA, steps/day**                                    | **4206 (2387-6284)** |

Values are presented as median (IQR) unless otherwise indicated.

GP: general practice; PR: pulmonary rehabilitation; ICS: inhaled corticosteroids; FEV$_1$: Forced Expiration Volume in 1 s; BMI: body mass index; 6MWD: six minute walking distance; DPA: daily physical activity

Correlations

Spearman’s correlations for all variables with DPA are shown in Table 3. Correlations of functional variables with psychological variables are shown in the supplementary material (e-Table 1). In general, patients with low functional status show weaker associations of DPA with psychological factors (anxiety, depression, self-efficacy; all rho’s≤0.20 and non-significant) and stronger associations of DPA with variables reflecting functional capacity (except SGRQ impacts all rho’s >0.20, all p<0.05) (Table 4).
For patients with higher functional status associations of DPA with psychological variables are significant for self-efficacy and depression. In addition, in patients with higher functional status, less of the variables reflecting functional capacity are significantly associated with DPA than in patients with low functional status (only 6MWD, SGRQ activity, CCQ function and DEFS).
In the stepwise multiple linear regression model 6MWD and SGRQ activity were predictors of DPA (Table 5). The model explains 37% of the variance, in which psychological variables did not contribute significantly. To further assess the contribution of psychological factors on DPA we performed a stepwise multiple linear regression containing only the psychological variables (Table 6). This model explains 16% of the variance with only PPAS (self-efficacy) as a significant independent predicting variable.

### Table 3. Spearman’s correlations of DPA with functional and psychological variables

| Variable                              | Correlation |
|---------------------------------------|-------------|
| FEV₁, l                               | 0.418 **    |
| RV%TLC, %                             | 0.253 **    |
| 6MWD, m                               | 0.627 **    |
| GARS total                            | -0.530 **   |
| SF-36 physical functioning            | 0.477 **    |
| SGRQ activity                         | -0.565 **   |
| SGRQ impacts                          | -0.405 **   |
| CCQ functional                        | -0.510 **   |
| DEFS                                  | -0.509 **   |
| PPAS                                  | 0.410 **    |
| HADS anxiety                          | 0.156       |
| HADS depression                       | -0.191 *    |
| SRQ-E                                 | -0.005      |

* Correlation is significant at the 0.05 level (2-tailed).
** Correlation is significant at the 0.01 level (2-tailed).

FEV₁: Forced Expiration Volume in 1 s; DPA: daily physical activity; 6MWD: six minute walking distance; GARS: Groningen Activity Restriction Scale; SF-36: Short Form 36; SGRQ: St George Respiratory Questionnaire; CCQ: Clinical COPD Questionnaire; DEFS: Dutch Exertion and Fatigue Scale; PPAS: Perceived Physical Ability Subscale of the Physical Self Efficacy Scale (Dutch version); HADS: Hospital Anxiety and Depression Scale; SRQ-E: Self Regulation Questionnaire for Exercise.
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Structural equations model

Based on the results of the regression analyses we hypothesized that psychological variables might indirectly affect DPA by affecting variables reflecting functional capacity. Path coefficients (standardized regression coefficients) are shown in Figure 1 indicating a possible causal linkage between the latent variables psychological capacity and functional capacity (0.45) and between the latent variable functional capacity and steps/day (0.62). Analysis of the model fit shows a $\chi^2 = 161.8$, (df=63); $p<0.001$ and RMSEA= 0.10. The model shows a clear, but indirect, association between psychological variables and DPA. A model with a direct association of psychological capacity with DPA was tested as well, but this association was very low and not significant. The fit of the model meets the criteria of the relative normed $\chi^2$ ($\chi^2$/df) of Wheaton et al. and the criteria of the RSMEA.34,35

### Table 4. Correlations of DPA for low and high functional status separately

|                      | Low functional status (6MWD< 452) | High functional status (6MWD≥ 452) |
|----------------------|----------------------------------|----------------------------------|
|                      | DPA (steps/day) | p                  | DPA (steps/day) | p                  |
| FEV1 (l)             | 0.312          | 0.009              | 0.137           | 0.247              |
| 6MWD (m)             | 0.454          | <0.001             | 0.375           | 0.001              |
| GARS total           | -0.344         | 0.004              | -0.228          | 0.053              |
| SF 36 physical function | 0.287         | 0.017              | 0.151           | 0.199              |
| SGRQ activity        | -0.288         | 0.016              | 0.357           | 0.002              |
| SGRQ impacts         | -0.091         | 0.481              | -0.181          | 0.129              |
| CCQ function         | -0.247         | 0.038              | -0.251          | 0.032              |
| DEFS                 | -0.260         | 0.035              | -0.296          | 0.011              |
| PPAS                 | 0.201          | 0.101              | 0.393           | 0.001              |
| HADS anxiety         | -0.154         | 0.209              | -0.219          | 0.061              |
| HADS depression      | -0.033         | 0.791              | 0.283           | 0.015              |
| SRQ-E                | 0.091          | 0.459              | 0.075           | 0.530              |

p-values<0.05 printed bold

FEV1: Forced Expiration Volume in 1 s; DPA: daily physical activity; 6MWD: six minute walking distance; GARS: Groningen Activity Restriction Scale; SF-36: Short Form 36; SGRQ: St George Respiratory Questionnaire; CCQ: Clinical COPD Questionnaire; DEFS: Dutch Exertion and Fatigue Scale; PPAS: Perceived Physical Ability Subscale of the Physical Self Efficacy Scale (Dutch version); HADS: Hospital Anxiety and Depression Scale; SRQ-E: Self Regulation Questionnaire for Exercise
### Table 5. Resulting multiple regression model for explaining DPA from functional and psychological variables (method stepwise)

|                | Unstandardized Coefficients | Standardized Coefficients |
|----------------|----------------------------|---------------------------|
| (Constant)     | 2703.165                   |                           |
| 6MWD (m)       | 7.899                      | 0.378                     |
| SGRQ activity  | -0.016                     | -0.275                    |

R²=0.37, adjusted R²=0.36

6MWD: six minute walking distance; SGRQ: St George Respiratory Questionnaire

### Table 6. Resulting multiple regression model for explaining DPA from psychological variables (method stepwise)

|                | Unstandardized Coefficients | Standardized Coefficients |
|----------------|----------------------------|---------------------------|
| (Constant)     | 557.866                    |                           |
| PPAS           | 143.131                    | 0.400                     |

R²=0.16, adjusted R²=0.15

PPAS: Perceived Physical Ability Subscale of the Physical Self Efficacy Scale (Dutch version)
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Figure 1. The path diagram shows the causal relationships (bold arrows) between the latent variables psychological capacity, functional capacity and DPA. The strength of this relationship is shown by the path coefficient (standardized regression coefficient). The relationship of the observed variables with the latent variables is specified by the correlation coefficient.

FEV₁: Forced Expiration Volume in 1 s; 6MWD: six minute walking distance; GARS: Groningen Activity Restriction Scale; SF-36: Short Form 36; SGRQ: St George Respiratory Questionnaire; CCQ: Clinical COPD Questionnaire; DEFS: Dutch Exertion and Fatigue Scale; PPAS: Perceived Physical Ability Subscale of the Physical Self Efficacy Scale (Dutch version); HADS: Hospital Anxiety and Depression Scale; SRQ-E: Self Regulation Questionnaire for Exercise.
DISCUSSION

DPA level in our COPD population was low, with a median (IQR) of 4206 (2387-6284) steps per day, which is considered to be sedentary. In the univariate analysis, DPA was significantly associated with variables reflecting functional capacity (performance-based and self-reported), and with psychological variables (depression and self-efficacy). When subjects were divided in having lower or higher functional status, DPA in patients with a lower functional status showed significant associations with seven of the variables reflecting functional capacity (i.e. FEV1, 6MWD, GARS total, SF-36 physical function, SGRQ activity, CCQ function and DEFS), whereas DPA in patients with a higher functional status showed significant associations with only four of these variables (i.e. 6MWD, SGRQ activity, CCQ function and DEFS). In addition, DPA in patients with a higher functional status was significantly associated with two psychological variables (i.e. self-efficacy and depression), which was not found in patients with low functional status.

Multivariate analysis showed only two significant variables, both reflecting functional capacity (6MWD and SGRQ activity) explaining 37% of the variance of DPA. However, the structural equations model (SEM) suggests that psychological variables indeed do contribute to DPA, but indirectly, through an effect on variables reflecting functional capacity.

Functional capacity and daily physical activity

The observed associations of DPA with variables reflecting functional capacity in the regression analyses and structural equations model are in line with other studies in COPD showing a relationship of higher DPA with higher FEV1, higher general quality of life (SF-36), and higher disease specific quality of life (SGRQ and CCQ). The 6MWD, which explained the largest part of the variance in our multiple regression model, was also found to be a determining factor in three other studies. We hypothesize that the relationship between functional capacity and DPA is reciprocal: better functional capacity indeed enables a higher DPA level, but on the other hand a higher DPA level will lead to better functional capacity.

Fatigue may negatively affect DPA level, which leads to deconditioning and consequently contributes to the vicious circle of dyspnea and fatigue.

Psychological capacity and daily physical activity

The relationship of DPA with psychological factors in COPD is less clear than the relationship with variables reflecting functional capacity. In our study, having higher self-efficacy and less depressive symptoms were associated with higher DPA. However, self-efficacy and depressive symptoms were not independent determinants of DPA in a multiple regression model which also included variables reflecting functional capacity. Nevertheless, in a model that included only psychological variables, self-efficacy explained a considerable part of the total variance.
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(16%). This relationship of higher DPA with higher self-efficacy has been shown as well in two other studies in COPD. Depressive symptoms, however, were not related to DPA in two earlier studies. This difference in findings might be caused by the use of a different questionnaire (Beck Depression Index) or lack of power in the second, small study.

In other populations than COPD there is some evidence for a relationship of DPA with psychological variables. For instance, in healthy elderly and in subjects at risk for diabetes higher scores on self-efficacy were related to higher DPA levels. In addition, in subjects at risk for diabetes having less symptoms of anxiety and depression was also related to higher DPA levels.

Interaction of functional and psychological capacity

Psychological variables affected DPA indirectly by influencing functional variables in our study, which is supported by several other studies in COPD. Cross-sectionally it has been shown in one study that a higher score on depressive symptoms is predictive for a lower walking distance (6MWD). In addition, two longitudinal studies aiming at treatment of symptoms of depression and anxiety gave insight into the relationship between psychological factors and 6MWD. The first study demonstrated that cognitive behavioral therapy and education both improved levels of depression and anxiety and performance in 6MWD. The second study compared pulmonary rehabilitation combined with psychotherapy to pulmonary rehabilitation alone. Both treatment arms improved walking distance, but it appeared that only pulmonary rehabilitation + psychotherapy improved scores of anxiety and depression. In summary, the results suggest at least a close, but not clearly understood, relationship between psychological variables and variables reflecting functional capacity, which might be reciprocal.

A strong point in our study is the use of structural equations modeling (SEM), which provides a more extensive insight in the complex relationship of DPA with functional and psychological variables. In addition, the broad group of studied COPD patients warrants better validity than studies with more specific groups of patients did. Although the number of participants per subgroup (healthcare setting) seems limited we believe we selected sufficient patients from three different healthcare settings. We think that our results are therefore valid for patients as they are present in usual care. Moreover, our extensive set of instruments covered more aspects of related factors than earlier studies.

There are some limitations. The patient group in this study was rather small to perform a path analysis, which might have caused the moderate fit of the model. However, the values in the model are well interpretable and no negative error variance or associations >1 were shown, which indicates a fair causal model. Another limitation is that DPA was measured with a pedometer, which is less accurate than an accelerometer. The Yamax Digiwalker, however, has shown to be the most accurate pedometer at moderate to slow gate speed and only tended to underestimate the number of steps at very low gate speed. Furthermore, pedometers are more accurate than questionnaires and diaries, less expensive and time consuming than double labeled water or direct observation, and easy to use, and therefore allow inclusion of a large cohort.
In conclusion, DPA levels in COPD are low. A better functional capacity is strongly and independently associated with higher levels of DPA. Psychological factors such as anxiety, depression and self-efficacy also affect DPA, but indirectly by an effect on functional capacity. Finally, the influence of psychological factors seems larger in patients with better functional capacity. There is a need for investigating whether treatment of psychological factors should be addressed when patients enroll in an exercise training or physical activity counseling program and whether the effects depend on functional capacity.
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SUPPLEMENTARY DATA

e-Table 1. Spearman’s correlations of variables reflecting functional capacity and psychological capacity

|                  | FEV₁ (l) | 6MWD (m) | GARS total | SF-36 physical function | SGRQ activity | SGRQ impacts | CCQ functional | DEFS | PPAS | HADS anxiety | HADS depression |
|------------------|----------|----------|------------|-------------------------|---------------|--------------|----------------|------|-----|--------------|----------------|
| 6MWD (m)         | 0.597 ** |          |            |                         |               |              |                |      |     |              |                |
| GARS total       | -0.572 **| -0.765 **|            |                         |               |              |                |      |     |              |                |
| SF-36 physical function | 0.627 ** | 0.772 ** | -0.847 ** |                         |               |              |                |      |     |              |                |
| SGRQ activity    | -0.604 **| -0.747 **| 0.849 **   | -0.833 **               |               |              |                |      |     |              |                |
| SGRQ impacts     | -0.512 **| -0.628 **| 0.754 **   | -0.750 **              | 0.829 **      |              |                |      |     |              |                |
| CCQ functional   | -0.575 **| -0.691 **| 0.800 **   | -0.816 **              | 0.853 **      | 0.832 **     |                |      |     |              |                |
| DEFS             | -0.557 **| -0.753 **| 0.847 **   | -0.824 **              | 0.838 **      | 0.754 **     | 0.773 **       |      |     |              |                |
| PPAS             | 0.425 ** | 0.532 ** | -0.597 **  | 0.623 **               | -0.603 **     | -0.567 **    | -0.621 **      | -0.592 ** |     |              |                |
| HADS anxiety     | -0.108   | -0.083   | 0.249 *    | -0.228 *               | 0.295 **      | 0.300 **     | 0.289 **      | 0.289 **  | 0.375 ** |              |                |
| HADS depression  | -0.136   | -0.190   | 0.372 **   | -0.346 **              | 0.355 **      | 0.369 **     | 0.374 **      | 0.411 **  | -0.449  | 0.678 **     |                |
| SRQ-E            | -0.088   | -0.101   | 0.034      | -0.116                 | 0.020         | 0.029        | 0.012         | -0.001    | 0.069   | -0.264 *     | -0.237 *       |

*p<0.05, ** p <0.01

FEV₁: Forced Expiration Volume in 1 s; 6MWD: six minute walking distance; GARS: Groningen Activity Restriction Scale; SF-36: Short Form 36; SGRQ: St George Respiratory Questionnaire; CCQ: Clinical COPD Questionnaire; DEFS: Dutch Exertion and Fatigue Scale; PPAS: Perceived Physical Ability Subscale of the Physical Self Efficacy Scale (Dutch version); SRQ-E: Self Regulation Questionnaire for Exercise.
