**The influence of pain, kinesiophobia, and psychological comorbidities on the accuracy of rating of perceived exertion in UK military spinal rehabilitation**

**KEY MESSAGES**

1. Monitoring exercise intensity and musculoskeletal pain during inpatient rehabilitation in the UK Military has been highlighted as a research priority among rehabilitation practitioners.

2. Pre-exercise pain and self-reported disability negatively affect the use of rating of perceived exertion (RPE) intensity in UK Military inpatient chronic low back pain (CLBP) patients.

3. Favourable changes in pre-exercise pain and comorbidities correlate with increased accuracy of the use of RPE for ongoing independent rehabilitation.

4. Further research is required to determine the short-term accuracy of RPE in CLBP patients, and how this changes over time in response to rehabilitation interventions.

**ABSTRACT**

***Introduction:*** Chronic low back pain (CLBP) is a leading cause of disability in the UK Military. Pain and psychological comorbidities have been reported to influence rate of perceived exertion (RPE). Exercise rehabilitation can be monitored using RPE; however, the accuracy of RPE in inpatient CLBP rehabilitation is unknown. ***Methods:*** A prospective cohort correlation study of 40 UK Military CLBP inpatients was completed. Disability (ODI), kinesiophobia (TSK), anxiety, (GAD7) and depression (PHQ9) were subjectively reported at the beginning and end of the 3-weeks. Pain (VAS) and heart rate (HR) were recorded in the first aerobic exercise (AE) session (T1), and the final aerobic exercise session (T2). RPE was reported for each AE session. ***Results:*** At T1, a positive correlation was observed between RPE accuracy (-7.2 ± 20.9), and pre-exercise pain (2.7mm ± 1.6mm) (*p* > .001) and ODI (31.0 ± 16.9) (*p* > 0.05), and a negative relationship between RPE accuracy and average HR (135 bpm ± 22 bpm) (*p* > 0.001) was observed. At T2 there was no significant correlation between RPE accuracy (-4.4 ± 22.6) and pre-exercise pain (2.8mm ± 1.6mm) or ODI (34.0 ± 16.5) (*p* > .05). The strong negative relationship between RPE accuracy and average HR (137 bpm ± 20 bpm) remained at T2. Improved RPE accuracy over the 3-week rehabilitation programme was correlated to the change in average HR (*r* = -.314, *p* < .05). ***Conclusions:*** Comorbidities may negatively affect RPE accuracy in CLBP, but the magnitude of the influence reduces over intensive rehabilitation.

**INTRODUCTION**

Chronic lower back pain (CLBP) is the leading cause of disability worldwide.1 Identifying significant nociceptive drivers that contribute to the presence of CLBP is central to CLBP rehabilitation.1 It has been reported that up to 20% of cases remain symptomatic or follow a recurring pattern more than one year from the onset.2 This trend is consistent in the UK Military as low back pain has higher re-referral rates than any other musculoskeletal condition.3 Traditional postural or co-contraction motor control exercise emphasis and/or passive interventions beyond the normal tissue healing time may reinforce negative pain beliefs and negatively influence function through fear avoidant behaviour (kinesiophobia).4 Previous research supports the impact of multidisciplinary team (MDT) rehabilitation programmes that target psychology, kinesiophobia, and exercise rehabilitation.5 These models include strength and conditioning principles, with an emphasis toward functional activity rather than mechanical dysfunction such as core stabilisation.2 Resistance exercise (RE) and aerobic exercise (AE) are leading contributors to improved function and pain in musculoskeletal rehabilitation.6,7 Favourable prognosis for CLBP is dependent on appropriate manipulation of AE and RE over time, such as training volume and/or intensity.8,9 Such evidence indicates that there has been a paradigm shift in the management of CLBP.

Managing musculoskeletal pain during inpatient rehabilitation in the UK military has recently been highlighted as a research priority among rehabilitation practitioners working within UK defence rehabilitation.10 While exercise is an important intervention, it can be a lead contributor to pain exacerbation.11 Equally, a sedentary lifestyle may result in sensitisation and consequently, persistent pain.12 The cycle of exceeding tolerable exercise, followed by periods of low activity is described as a “boom-bust cycle”, and demonstrates poor exercise load managment.13 Centralised pain pathways become increasingly more sensitised the more frequently they are acutely exacerbated.14 Paradoxically, progressive exposure to activities which often cause pain is advised, with the intent to provide exposure without adverse experience as often as possible.15 A positive experience following exposure to an activity that a patient was initially fearful of, is crucial for the desensitisation of CLBP.16 The underlying pathology of CLBP can be multifactorial, and may provoke sympathetic neurophysiological responses. Symptoms of a sensitised sympathetic nervous system response include perspiring, rapid apical breathing rate, increased heart rate (HR), muscular contraction excitability, increased intramuscular hemodynamics (vasodilation), altered proprioceptive sensitivity, and either increased or decreased nociceptive feedback.17 Such physiological changes may influence subjective perceived exertion and consequently the ability to appropriately self-regulate activity intensity.

To ensure that exercise rehabilitation is individualised, it is advantageous to monitor exercise and enable the patient to self-regulate their rehabilitation programme using a rating of perceived exertion (RPE). The Borg RPE scale (a 15-point numerical scale ranging from 6-20) and has been seen to correlate with HR across a range of different training activities by using a Borg RPE equation (Borg RPE x 10).18,19 An accurate Borg equation is reported to be within range of 6-7 beats per minute from the average HR.20

Finucane and colleagues21 studied the clinical validity of RPE used for AE in CLBP rehabilitation and reported strong correlations between HR and Borg RPE, suggesting validity in clinical use; however the self-reported disability of their population was very mild. In line with these findings, Demoulin and colleagues22 investigated the impact pain has on RPE in CLBP and found that the ability to predict HR with RPE (Borg RPE x 10) was moderately effective and revealed no associations with pain or disability. However, the exclusion criteria for their population was extensive and 35% of the participants did not complete the 10-week exercise intervention due to clinical reasons. Barker and colleagues23 supported these findings at exercise intensities of >55% age-predicted maximum HR but found that lower intensity exercise was unreliable, postulating that pain may affect the perception of exertion. Contrary to these findings, Wallbom et al8 found that in CLBP, RPE was not highly correlated with physiological effort and postulated that psychological comorbidities and kinesiophobia may have negatively influenced RPE accuracy. In contrast to the aforementioned studies, the exclusion criteria in the study by Wallbom was less extensive, capturing a greater range of conditions within the CLBP population. It may be inferred that the greater the complexity of CLBP history, the less reliable RPE may be as a subjective measure of exercise intensity. The limited and inconsistent findings within this demographic demand more conclusive evidence.

This study intended to investigate the impact of pain, disability, kinesiophobia, and psychological comorbidities on RPE accuracy. The primary hypothesis was that there would be a positive correlation between high scoring pain, disability, kinesiophobia, and psychological comorbidities and RPE accuracy (the difference between HR and Borg RPE equation). The secondary hypothesis was that a favourable change in the aforementioned comorbidities over the course of inpatient rehabilitation would positively correlate with reduced RPE accuracy.

**METHODS**

**Design**

We conducted a prospective observational cohort study design using a correlational analysis to determine the impact of pain, disability, kinesiophobia, and psychological comorbidities on the accuracy of the Borg RPE.

**Participants**

Thirty-seven participants were required to achieve a statistical power of >.80 with an alpha of .05, determined by an *a priori* analysis, a large effect size was assumed.22 The participants were UK Military personnel inpatients at the Defence Medical Rehabilitation Centre (DMRC) Stanford Hall that had been previously enrolled on a 3-week exercise rehabilitation programme; as such, there was no further inclusion criteria. Participants presented with CLBP with a minimum symptomatic history of 3-months, with or without radicular leg pain or history of surgical intervention. As this was a service evaluation we did not require MOD ethical approval; however, ethical approval was granted from St Mary’s University ethics committee (reference: SMEC\_2018-19\_010). Participant information was handled in line with the MoD confidentiality policy (Caldicott - Protecting and Providing Information at DMRC) and the General Data Protection Regulation. Before consent, participants were informed of the purpose of the study and made aware that they could withdraw from the study at any point.

**Procedure**

The participants were initially assessed by the programme medical Consultant for suitability to participate in exercise rehabilitation, and then later in the same day assessed by each of the MDT as part of the standardised programme admission procedure (supplementary file).

**Outcomes**

Participants completed all patient reported outcome measures (PROMs) on day 1 of the rehabilitation programme (Table 1). The battery of PROMs used were part of an existing inpatient rehabilitation programme and not specifically selected for this study.5 The details and validity of the PROMs have been previously outlined.5 The participants completed an AE rehabilitation session on day 2 (T1). Before the AE session, each participant completed a 100mm visual analogue scale (VAS) pain score with the anchors ‘no pain’ on the left, and ‘worst possible pain’ on the right, which demonstrates good accuracy in patients with CLBP.24 They were invited to strike through the scale they perceived their pain to be at that point in time. Each participant wore a Polar H10 Bluetooth HR monitoring belt (Polar Electro, Kempele, Finland) which was synchronised to an iPad (Apple Inc., Cupertino, California, USA) loaded with Polar Team (Version 1.5, iOS 10.0, Polar Electro OY, Kempele, Finland).

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| --- | --- | --- | --- |
| **Outcome measure** | **Description** | **Scoring** | **Clinically meaningful difference value** |
| **ODI** | A 10-section form used to quantify participant reported disability. | 0-20 mild disability, 21-40 moderate disability, 41-60 severe disability, 61-80 crippled, 81-100 bed bound or exaggerating symptoms. | ≥ 10 points |
| **TSK**  | A 17-item self-reported fear of movement and re-injury questionnaire measure. | >37 indicates the presentation of kinesiophobia. ≤37 indicates no clinical presentation of kinesiophobia. | ≥ 8 points |
| **PHQ-9** | A 9-item self-reported questionnaire used to quantify participant reported depression | 5-9 mild,10-14 moderate,15-19 moderately severe≥20 severe | ≥ 5 points |
| **GAD-7** | A 7-item self-reported questionnaire used to quantify participant reported anxiety. | 5-9 mild,10-14 moderate,15-21severe. | Not previously determined |
|  |  |  |  |

**Table 1.** Patient reported outcome measures completed at admission and discharge.

*Abbreviations:* GAD-7 = General Anxiety Disorder-7; ODI = Oswestry Disability Index; PHQ-9 = Patient Health Questionnaire-9; TSK = Tampa Scale of Kinesiophobia.

The AE rehabilitation session was part of a 3-week rehabilitation programme which includes a range of cognitive and functional therapy (Table 2). The AE session duration was 30 minutes, which is in accordance with previous AE assessment of HR and RPE in CLBP patients.22 The aim of the rehabilitation session was to maintain exercise intensity within the limitations of symptom exacerbation. Self-selection of equipment and intensity was required to ensure success in their rehabilitation goal of managing symptoms appropriately, but also to maximise adherence to the study procedure. Therefore, each participant selected their own choice of exercise equipment from a range within a cardiovascular fitness suite and attempted to maintain a continuous self-selected intensity.

**Table 2.** Descriptive outline of the components of inpatient rehabilitation sessions

|  |  |  |  |
| --- | --- | --- | --- |
| **Treatment type** | **Description** | **Therapy Goal** | **Duration (Frequency)** |
| **Therapeutic self-management** | Range of movement, self-myofascial release, yoga. | Supervised progressions and regressions and support to self-manage symptoms. Restore safe confident movement.  | 30,45, or 60 mins (10 per week) |
| **Resistance exercise/ IEP** | Fundamental strength sessions in week 1 provide the foundation for an IEP, which is specific to each patient.  | Designed for the patients to leave the programme with and self-manage by the manipulation of basic RE variables. The IEP based upon the patient goals. | 60 min (3 per week) |
| **Cardiovascular exercise** | Group based sessions designed to target energy systems. Aerobic and anaerobic session designs, using a broad range of equipment.  | Encourage and reassure safe participation in the development of the energy systems, whilst identifying barriers. Improve tolerance to mobility. Develop self-efficacy. | 30-45 min (3 per week) |
| **Swimming** | Technique based swimming instruction, therapeutic aqua jogging, and aquatic functional movement circuits. | Swim technique instruction targets modifying swimming style for specific pain patterns. Aquatic circuits promote unrestricted functional movement. | 30-45 mins (2 per week) |
| **Hydrotherapy** | Hydrotherapy: Aquatic mobility, functional movement, relaxation, diaphragmatic breathing.  | Application of therapeutic properties of hydrotherapy pool.  | 30 mins (8 per week) |
| **Patient education** | Patient centered goal setting, pain education, functional posture, and sleep hygiene. | Patient education is designed to enable patients to optimally self-manage their rehabilitation going forwards. | 30-45 mins (5 per week) |
| **Relaxation/ mindfulness** | Guided group relaxation, mindfulness, and Ai Chi. | Guided relaxation and mindfulness activity to target pain management. | 30-45 min (5 per week) |
| **1:1 Physiotherapy/ Occupational Therapy** | A thorough initial 1:1 assessment/interview will govern the 1:1 treatment plan. Subject education is central to 1:1 sessions.  | Physiotherapy targets education and self-management, but also may include manual techniques. The OT input targets functional ability in personal and domestic activities, productivity and leisure. | As required |
| **Supplementary Clinical input** | Specialist Pain Consultant, Clinical Psychologist, Pain Nurse, Mental Health OT, vocational support, and Social Worker. | Clinical specialists compliment the exercise rehabilitation programme. Specialist input is intended to enhance the final outcome of the rehabilitation programme.  | As required |

*Abbreviations:*  IEP = Individualised Exercise Programme; OT = Occupational Therapist; RE = Resistance Exercise.

In accordance with previous studies, average HR was calculated from the full final 5 minutes of the protocol.19 Following the rehabilitation session, the average HR score of each participant was documented. Each participant was required to rate the overall intensity of the session using the 15-point numerical scale Borg RPE, between 10 and 30 minutes post-session.8 For the recording of RPE, each participant was handed a device (Samsung Tab A 10.1, Samsung, Seoul, South Korea) with an individualised profile using a web-based questionnaire, which populated a database (Google Forms, Google, CA, USA). The same AE assessment protocol including HR, VAS and RPE scores were repeated on the penultimate day of the 3-week rehabilitation programme, and all PROMs were repeated on the final day (T2).

**Statistical Analysis**

Only participants who completed all clinical outcome measures were included in the analysis. The Borg score equation was calculated for each participant at T1 and T2 to measure the difference with average HR for the session, to determine the RPE accuracy (average HR – Borg score equation). A scatterplot graph was generated to inspect for outliers or violation of assumptions of linearity and homoscedasticity. A Pearson’s correlation coefficient was calculated to measure the relationship between RPE accuracy and pre-exercise pain and PROMs. This was repeated at T2. A Pearson’s correlation coefficient was then calculated to measure the relationship between the change in all variables between T1 and T2. The strength of the relationship was determined with a correlation coefficient value of .1, .3, and .5, representing small, medium, and large correlation strength respectively.25

**RESULTS**

Fifty-one participants were invited, of which 43 consented, and 8 declined participation in the study. Three participants were removed from analysis as they were unable to complete data collection (two due to conflicting appointments, and one due to acute pain symptoms). Forty participants completed the study, with a mean (standard deviation) age, height, and body mass of 34 years (± 7), 172.8cm (± 28.9), and 85kg (± 13.3) respectively. Of the 40 participants, 35 were male, and 5 were female.

Table 3 presents correlations between PROMs, VAS, HR, and RPE accuracy at T1 and T2. Statistically significant positive correlations were observed between PROMs at both T1 and T2; however extensive analysis is outside of the scope of this study.

At T1, a significant positive correlation was observed between RPE accuracy (-7.2 ± 20.9), and pre-exercise VAS (2.7mm ± 1.6mm) and ODI (31.0 ± 16.9) (Figure 1A and Figure 1E respectively). A strong negative relationship between RPE accuracy and average HR (135 bpm ± 22 bpm) was observed (Figure 1 C). At T2 there was no significant correlation between RPE accuracy(-4.4 ± 22.6) and pre-exercise pain (2.8mm ± 1.6mm), or ODI (34.0 ± 16.5) (*p* >0.05) (Figure1B and Figure 1F respectively). The strong negative relationship between RPE accuracy and average HR (137 bpm ± 20 bpm) remained at T2 (Figure 1 D).

**Table 3.** Correlational analysis of PROMs, pre-exercise pain, HR, and Borg score accuracy at T1, and T2

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **T1** | **ODI** | **TSK** | **PHQ-9** | **GAD-7** | **Pre-VAS** | **Ave HR** | **Borg score accuracy** |
| **ODI** | - | .461\*\* | .644\*\* | .461\*\* | .604\*\* | -292 | .323\* |
| **TSK** |  | - | .105 | .060 | .200 | -.142 | .269 |
| **PHQ-9** |  |  | - | .644\*\* | .505\*\* | -169 | .198 |
| **GAD-7** |  |  |  | - | .484\*\* | .035 | .089 |
| **Pre-VAS** |  |  |  |  | - | -.235 | .405\*\* |
| **Ave HR** |  |  |  |  |  | - | -580\*\* |
| **Borg score accuracy** |  |  |  |  |  |  | - |
|  |  |  |  |  |  |  |  |
| **T2** | **ODI** | **TSK** | **PHQ-9** | **GAD-7** | **Pre-VAS** | **Ave HR** | **Borg score accuracy** |
| **ODI** |  | .142 | .662\*\* | .688\*\* | .536\*\* | -.224 | .142 |
| **TSK** |  | - | .290 | .255 | .367\* | -.112 | .064 |
| **PHQ-9** |  |  | - | .931\*\* | .495\*\* | -.056 | .129 |
| **GAD-7** |  |  |  | - | .477\*\* | -.063 | .118 |
| **Pre-VAS** |  |  |  |  | - | .017 | .099 |
| **Ave HR** |  |  |  |  |  | - | -.561\*\* |
| **Borg score accuracy** |  |  |  |  |  |  | - |

\*Signifies a level of significance at p = <.05

\*\* Signifies a level of significance at p = <.001.

The relationship between changes in PROMs, pre-exercise pain, average HR, and RPE accuracy is presented in Table 4.

**Table 4.**  Correlations of change in PROMs, pre-exercise pain, average HR, and Borg score accuracy

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Measure** | **ODI** | **TSK** | **PHQ-9** | **GAD-7** | **Pre-VAS** | **Ave HR** | **Borg score accuracy** |
| **ODI** | - | -.183 | .084 | 1.24 | .085 | -1.95 | -.063 |
| **TSK** |  | - | .309 | -.023 | .149 | -.364\* | .306 |
| **PHQ-9** |  |  | - | .433\*\* | .244 | -.393\* | .019 |
| **GAD-7**  |  |  |  | - | .209 | -.215 | .226 |
| **Pre-VAS** |  |  |  |  | - | -252 | .229 |
| **Ave HR** |  |  |  |  |  | - | -.313\* |
| **Borg score accuracy** |  |  |  |  |  |  | - |

\*Signifies a level of significance at p < .05

\*\* Signifies a level of significance at p < .001.

The strength of the relationships are presented in Figure 2. There was a negative relationship between average HR and RPE accuracy (Figure 2A). There was a noteworthy positive trend between deterioration in TSK, and worsening RPE accuracy, however this was not statistically significant *(p* = 0.06) (Figure 2B). The mean RPE accuracy at T1 was 7 bpm below the recorded HR average. At T2, the mean RPE accuracy was 4 bpm below the recorded HR average, indicating an improvement in RPE accuracy.

**DISCUSSION**

The main finding from this study was that at baseline, pre-exercise pain and exercise intensity were most strongly related to poor RPE accuracy, followed by disability. However, at the end of the 3-week residential rehabilitation programme, only exercise intensity was related. The favourable change in RPE accuracy over the 3-week rehabilitation programme was only significantly related to increased average HR. Although not statistically significant *(p* = .06), there was a trend that over the inpatient rehabilitation programme RPE accuracy improved with favourable changes in kinesiophobia, and worsened with increased kinesiophobia. Further research is warranted to explore the potential relationship between kinesiohobia and RPE accuracy, and the response to rehabilitation.

Contrary to our findings, Demoulin et al22 found no association with RPE accuracy and pain over a 10-week outpatient rehabilitation programme. However, it may be inferred that many of the 35% of withdrawn participants were not responding as positively to the intervention as those that completed the intervention, thus the findings do not reflect RPE accuracy in CLBP rehabilitation. Our study was able to distinguish the impact of pain and comorbidities at baseline, and contrast with the end of the intervention period. Interestingly, we found that pain was strongly associated with RPE accuracy at the start of the rehabilitation intervention, but not at the end of the 3-week programme. It is noteworthy that the reported pain was not different between time-points, therefore the abolished relationship at T2 may have been due to the impact of patient education, pain medication, and/or favourable changes in kinesiophobia and psychological co-morbidities.

Finucane et al21 concluded that RPE was suitable for independent patient use as a method of self-guided exercise intensity; however the participants of their study were also not complex CLBP cases. Finucane et al21 reported that 67% of their participants were of minimal disability (only 10 % were severe, measured with ODI), and reported low pain levels. In contrast, our participant cohort presented as more complex with only 27% reporting minimal disability, 50% reporting moderate disability, and 20% reporting severe disability. Hence, we do not support the same practical recommendations due to the likely impact of comorbidities on RPE accuracy; although from our findings, we infer that it may be dependent on the response to rehabilitation, and that RPE may be suitable for either less complex CLBP patients, or patients that respond well to rehabilitation.

Our results support the hypothesis made by Wallbom et al8 that high scoring kinesiophobia may negatively affect the correlation between RPE and HR. Although not significant, we believe that the trend between the change in kinesiophobia and RPE accuracy is of clinical relevance. The sympathetic physiological response to exercise in high scoring kinesiophobic patients may contribute to the perceived exertion. We also believe that favourable changes in kinesiophobia may indeed reduce the physiological responses, and potentially improve RPE accuracy. Conway et al5 have previously reported positive clinical outcomes in psychological comorbidities and function in UK military CLBP patients. The findings of the aforementioned and the study by Wallbom et al8 support the trends we report in the present study.

Our results support the findings of Barker et al23 by demonstrating the same trend at lower intensity exercise, and that RPE accuracy is improved in CLBP patients that are able to tolerate exertion at a greater intensity. Moreover, Barker et al23 reported that the accuracy observed at lower HR may have been due to increasing pain levels which may have dominated the perception of exertion or indeed prevented exertion. We found no correlation between pain and average HR, therefore it may be inferred that increases in HR were attributed to exercise. In contrast with Barker et al23, the relationship between pre-exercise pain and RPE accuracy in our study changed over the 3-week programme. Despite exposure to a high volume of exercise within our 3-week programme, including a wide range of exercise modalities (including compound strength exercise), pain influenced RPE accuracy far less at the completion of the 3-week programme, compared with the beginning.

Considering the findings of our study, there is a strong suggestion that pre-exercise pain, exercise intensity and self-reported disability have a noteworthy relationship with the accuracy of RPE at the start of inpatient rehabilitation. Our findings demonstrate that favourable clinical changes over a 3-week rehabilitation programme may be associated with improved RPE accuracy. Our study did not differentiate the impact that each multidisciplinary clinician had on the inpatient CLBP rehabilitation, although the overall effect of the 3-week intervention can be attributed to a collaborative delivery.

**Limitations**

Participants were required to self-select the AE equipment used, which may provide significant differences in intensity perception between different modes of AE. Investigating exercise rehabilitation is challenging as a template programme with controlled variables lacks clinical individualisation. As the AE session instruction was to reduce exercise intensity in line with increasing pain, it is likely that the RPE throughout the session fluctuated for many of the participants, therefore the impact of the within group variation in intensity is unknown. Whilst the participants were educated on the Borg RPE, there was no familiarisation or learning protocol which has been demonstrated to be effective in improving the accuracy.26 The data capture of HR would have been more transparent had it been measured at intervals throughout the exercise protocol, and more frequently over a longer period of time; however, due to materials used, this was unachievable. However, all sessions were monitored by clinicians, and to our knowledge there was no significant exacerbations in pain that disrupted completion of the AE intervention as instructed. Our study was not able to detect whether a participant dropped exercise intensity throughout the session, resulting in a lower average HR in the final 5 minutes. Future research should explore whether HR fluctuation throughout an AE session impacts the validity of RPE used for post session Borg equation in CLBP rehabilitation.

**Conclusion**

There is a paradigm shift in the evidence base supporting CLBP rehabilitation, supporting strength and conditioning principles. The specific exercise selection is arguably not as important as the optimal training intensity; therefore it is important to be aware of RPE accuracy in CLBP rehabilitation. Pre-exercise pain, high AE exercise intensity, and disability have a negative impact on RPE accuracy at the start of intensive rehabilitation programmes and may invalidate the use of RPE. However, favourable changes in pre-exercise pain, disability, kinesiophobia and consistency in graduated progressive exercise intensity may increase the accuracy of RPE accuracy for ongoing independent rehabilitation. Further research is needed to explore the RPE accuracy in CLBP patients over a longer rehabilitation intervention.

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# **Figures**

**Figure 1.** Scatterplots showing the strength of relationships between statistically significant variables at T1, and T2. A and B represent the correlation between Borg score accuracy and pre-exercise pain at T1 and T2 respectively. C and D represent the correlation between Borg score accuracy and average HR at T1 and T2 respectively. E and F represent the correlation between Borg score accuracy and disability at T1 and T2 respectively. \*\*Significant correlation (*p <*.001); \*Significant correlation (*p* <.05).

**Figure 2.** Scatterplots showing the relationship between the change in variables over the 3-week rehabilitation programme. A represents the correlation between the change in Borg accuracy average HR change. B represents the correlation between the change in Borg accuracy and TSK change. \*Signifies a level of significance at p <.05.