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**The potential psychological benefits of Active Video Games in the rehabilitation of musculoskeletal injuries and deficiencies: A narrative review of the literature**

### Abstract

**Background:** Recent literature suggests that Active Video Games (AVGs) may offer potential psychological benefits during the rehabilitation of musculoskeletal injuries and their corresponding deficiencies. **Objectives:** To review existing literature regarding the potential psychological benefits of AVGs within the context of rehabilitation from musculoskeletal injury or debilitation. **Method:** A narrative review of the literature that used the *Population, Intervention, Comparison, and Outcomes* PICO method was conducted. The literature review included studies that discussed and/or investigated potential psychological benefits of AVGs during musculoskeletal rehabilitation. Of the total 163 papers that were identified, 30 met the inclusion criteria. **Results:** The *Nintendo*<sup>®</sup> *Wii*<sup>™</sup> (Nintendo Co., Ltd, Kyoto, Japan) was the most commonly-used games console that was employed in AVG interventions (15 out of 21), and these studies that investigated potential psychological benefits were typically conducted with elderly populations. These studies reported that using AVGs in musculoskeletal rehabilitation resulted in a number of positive psychological effects (e.g., enjoyment, effects on self). However, most studies lacked a clear theoretical framework, and varied greatly in their designs and methodologies. **Conclusion:** Despite encouraging findings of AVG use, insufficient evidence exists to reliably verify or refute the potential psychological benefits of AVGs in musculoskeletal rehabilitation. It is recommended that future studies in this area contain a theoretical framework to ensure greater consistency in the methodology used and the execution of the intervention. The potential findings of such investigations may result in the development of optimal, client-tailored rehabilitation programmes.

**Keywords:** Exergaming; Interventions; Musculoskeletal; Psychosocial recovery

## Introduction

1 Sport injury rehabilitation is typically considered to be successful when an athlete is both  
2 physically and psychologically ready to return to the athlete's sport.<sup>1,2</sup> Research conducted with  
3 athletic trainers and athletic training students suggests that being psychologically ready for  
4 competition may be just as important as being physically ready.<sup>1-3</sup> However, when rehabilitating  
5 injured athletes, traditionally the focus of rehabilitation has been on the obvious physical symptoms,  
6 and the psychological components may have been overlooked.<sup>4</sup> A key aspect of successful  
7 rehabilitation from musculoskeletal injury or debilitation is to ensure that the patient is able to cope  
8 effectively with the rehabilitation process.<sup>5</sup> Rehabilitation professionals (RPs) who include  
9 physiotherapists and related practitioners, believe that there are three principal characteristics which  
10 determine the degree to which a patient will cope successfully with the process of rehabilitation: (1)  
11 attitude (i.e., positive/negative), (2) mood (i.e., stress, anxiety, anger, depression), and (3)  
12 rehabilitation behaviour i.e., adherence/compliance with rehabilitation;<sup>6,7-9</sup> All three of the above  
13 characteristics are psychological constructs that influence overall physical and psychological  
14 recovery and rehabilitation outcomes.<sup>10</sup> These studies identify a number of strategies that RPs  
15 report using to facilitate a successful coping with the injury and subsequent rehabilitation process  
16 and return to activity following recovery. According to the RPs self-reported views, the three most  
17 commonly used strategies are: (1) creating variety in rehabilitation exercises, (2) setting short-term  
18 goals, and (3) encouraging positive self-thoughts.<sup>6-9</sup> Each strategy, if used appropriately and  
19 effectively, can facilitate beneficial change in the patient's attitude, mood, and/or rehabilitation  
20 behaviour.<sup>10</sup>

22           One way in which RPs could create variety in rehabilitation exercises is by incorporating  
23 Active Video Games (AVGs) as an adjunct to, or replacement for, more traditional rehabilitation  
24 modalities. Many traditional proprioceptive rehabilitation activities are unable to sustain injured  
25 patients' interest,<sup>11</sup> and in addition to the possible negative effects on injury recovery that may  
26 manifest themselves physically, a patient's loss of interest in performing rehabilitation activities  
27 may also have a negative effect on injured patients' attitude, mood, and rehabilitation behaviour.<sup>6, 7</sup>  
28 Indeed, playing with AVGs during rehabilitation has been proposed as having a positive impact  
29 on patients' balance and motion,<sup>12</sup> strength and flexibility,<sup>13</sup> enjoyment,<sup>14</sup> motivation,<sup>15</sup> and  
30 adherence,<sup>16</sup> as well as assisting clients who are experiencing too much pain or anxiety for them  
31 to relax.<sup>13</sup>

32           Despite the above claims, limited empirical research has been conducted to date that  
33 investigates the actual beneficial psychological impact of AVGs used during rehabilitation  
34 sessions. For example, Butler and Willet<sup>17</sup> discussed the potential for AVGs as a means of  
35 enhancing the psychological factors associated with successful rehabilitation from injury.  
36 However, their article only discussed the potential benefits, and did not include empirical  
37 intervention to test their claims, and did not contain a review of the relevant extant literature that  
38 currently exists. A concerted review of the literature regarding studies that employed AVG use  
39 is necessary in order to gain a better understanding of *how* AVGs may impact patients'  
40 psychological responses to the rehabilitation process, and obtain a comprehensive understanding  
41 of the theoretical frameworks used to underpin such interventions. Therefore, the purpose of this  
42 review is to conduct an evaluation of the existing literature which has examined the role of AVGs  
43 that are used in the rehabilitation of musculoskeletal injury or impairment, specifically focused on

44 the psychological responses to the rehabilitation process. The present review aims to answer the  
45 following research questions:

- 46 (1) What patient populations have reportedly used AVGs within the context of  
47 musculoskeletal rehabilitation?
- 48 (2) What AVG consoles have been used in the context of musculoskeletal rehabilitation?
- 49 (3) What psychological benefits have been found to exist when using AVGs as part of  
50 musculoskeletal rehabilitation programme?
- 51 (4) What psychological theoretical frameworks underpin the use of AVGs in the context  
52 of musculoskeletal rehabilitation?
- 53 (5) How can AVGs be used most effectively in the context of musculoskeletal  
54 rehabilitation?

## 55 **Methods**

### 56 *Search strategy*

57 The development of these research questions, and the subsequent search strategy that was  
58 employed was underpinned by the *Population, Intervention, Comparison, and Outcomes* (PICO)  
59 approach.<sup>18</sup> For the purposes of this study, each part of the PICO acronym is defined as follows:

60 *Population:* patients with musculoskeletal injuries or deficiencies undergoing some form  
61 of structured rehabilitation programme;

62 *Intervention:* Active Video Games (AVGs) are video games which require some form of  
63 physical activity or movement when played;

64 *Comparison:* different AVG consoles (e.g., *Nintendo*<sup>®</sup> *Wii*<sup>™</sup>, *Microsoft*<sup>®</sup> *Xbox 360*<sup>®</sup> with  
65 *Kinect*<sup>™</sup>; Microsoft Corporation, Redmond, WA, USA);

66 *Outcome: the psychological benefits of AVGs as part of musculoskeletal rehabilitation.*

67 The above definitions for PICO were used to inform the subsequent identification of  
68 relevant sources, the keyword combinations that were used in searches conducted, and the  
69 inclusion/exclusion criteria for the papers that were identified from these searches.

#### 70 ***Sources and keywords***

71 Two distinct sources of article retrieval were used for this study: First, electronic  
72 database searches were employed. These included: Academic Search, Bielefeld Academic  
73 Search Engine (BASE), CAB Abstracts, Cochrane Library, Cumulative Index to Nursing and  
74 Allied Health (CINAHL), CORE, FreeFullPDF, Google Scholar, IEEE Xplore, IngentaConnect,  
75 Mendeley, PsycINFO, PubMed, ScienceDirect, SPORTDiscus, and WorldWideScience. Second,  
76 the citations within the papers that had been retrieved from the electronic database searches were  
77 also scrutinized. When conducting the article retrieval, the Boolean operators, AND and OR  
78 were used when searching for keyword combinations. The keyword combinations included the  
79 following words and their variations: *virtual reality, audiovisual gaming, active video gaming,*  
80 *AVG, rehabilitation, Nintendo® Wii™, Wii™, Wii Fit™, Xbox® Kinect™, PlayStation Move®,*  
81 *Wii-habilitation, sports injury, motion games, balance control, adherence, athletic training,*  
82 *physical therapy, physiotherapy, sports therapy, musculoskeletal, exergame(s), and functional.*

#### 83 ***Inclusion criteria***

84 Inclusion criteria were limited to research studies that specifically assessed psychological  
85 outcomes. Due to this being a novel area of research, no publication date limits were applied to  
86 the literature search. The literature review was limited to articles published in peer-reviewed  
87 journals, conference proceedings, abstracts, and unpublished theses that were written in English.

88 The review encompasses all published research studies that were conducted in sports, physical  
89 activity, and other non-neurological injury or illness rehabilitation domains. Particular focus  
90 included the role of AVGs in relation to the five research questions as stated in the aims that  
91 were explicated previously, specifically the identification of *psychological benefits* within the  
92 context of musculoskeletal rehabilitation. In addition, given the scarcity of research in this  
93 domain, and the overlap between certain injury rehabilitation and injury prevention programmes  
94 (e.g., fall prevention programmes and the rehabilitation of musculoskeletal injuries resulting  
95 from a fall), publications which examined or discussed the psychological benefits of AVGs when  
96 applied to programmes that were designed to increase musculoskeletal fitness/form/functioning  
97 were also included in this review.

#### 98 ***Procedure***

99 The search yielded a total of 163 publications. Both electronic and hard copies of the extracted  
100 publications were obtained for the creation of a master table that includes all 163 publications.  
101 This master table consists of the following information: publication authors, year of publication,  
102 publication type (e.g., media, conference proceedings, journal article, thesis), availability of full  
103 text publication, type of rehabilitation (e.g., in-patient, out-patient, home rehabilitation, sport  
104 injury, brain/stroke injury, inactivity intervention), the AVG platforms used (e.g., *Nintendo*<sup>®</sup>  
105 *Wii*<sup>TM</sup>, *Microsoft*<sup>®</sup> *XBox 360*<sup>®</sup> *with Kinect*<sup>TM</sup>, *PlayStationMove*<sup>®</sup> [Sony Computer Entertainment  
106 America LLC, San Mateo, CA, USA], or other), details of the participants (e.g., *N*, age, gender),  
107 outcome measures used (e.g., functional, psychological), and overall, those outcomes of the  
108 study reviewed (for details of the studies included in the final analyses, please see Table 2 in the  
109 Results section).





132 Specifically, the review aimed to answer five research questions, each of which will be presented in  
133 the sections that follow. Table 2 displays details of the studies that were reviewed and are included  
134 in the final analyses.

135 INSERT TABLE 2 ABOUT HERE

136 ***Question 1: What patient populations have reportedly used AVGs within the context of***  
137 ***musculoskeletal rehabilitation?***

138 Of the studies included in the analyses, seven studies used AVGs as part of a balance  
139 training programme. Two studies<sup>19,20</sup> used AVGs as part of a fall prevention programme, while a  
140 total of five studies investigated the usefulness of AVGs as part of a musculoskeletal dysfunction  
141 programme (e.g., injury rehabilitation, teaching motor skills/motor disability, upper extremity  
142 dysfunction, impaired stepping). Only Manley, Arvinen-Barrow and Wallace<sup>21</sup> recruited injured  
143 athletes as participants for their study. In their multi-method intervention study, Manley et al. first  
144 conducted trials of AVG activities with previously injured athletes. After the trials, the athletes  
145 were interviewed about their perceptions and experiences of the usefulness of AVGs in relation to  
146 their sport injury rehabilitation. The results from the study indicated that despite elite athletes  
147 feeling more skeptical about the efficacy of AVGs within the context of sport injury rehabilitation,  
148 overall the athletes perceived AVGs as potentially effective adjunct to traditional injury  
149 rehabilitation programs in two ways: (1) enhancing positive emotional responses, and (2) increasing  
150 adherence to the rehabilitation process.

151 A total of ten articles explored the potential benefits of using AVGs as an intervention for  
152 exercise enhancement (with the aim of improving exercise attendance, fitness, muscular strength,  
153 balance, etc.). Eight of the 30 articles discussed the usefulness of AVGs in rehabilitation or as a

154 form of therapy, while one study<sup>19</sup> examined the motivation and gaming experience related to AVG  
155 use.

156 Typically, the populations used in the investigations varied from young adults to older adults  
157 (Age range = 16-94 years). A total of six studies used young adults or collegiate students, of which  
158 all but one<sup>20</sup> used healthy participants with no current injuries or impairments.<sup>19, 21-24</sup> Several  
159 studies ( $n = 8$ ) used healthy adults as participants, who were usually recruited from health care  
160 centres. The majority of empirical studies, however, had been conducted with older adults (study  
161 sample ages ranged from 50 to 94) who were either (a) independent community dwelling older  
162 adults, or (b) those living in assisted living facilities and (long term) continuing care facilities.

163 ***Question 2: What AVG consoles have been used in the context of musculoskeletal (sport) injury***  
164 ***rehabilitation?***

165 Of the 21 empirical studies included in the analyses, 15 studies<sup>19, 21-34</sup> used *Nintendo Wii*<sup>®</sup>  
166 platforms (*Nintendo*<sup>®</sup> *Wii*<sup>TM</sup>  $n = 8$ , and *Nintendo*<sup>®</sup> *Wii*<sup>TM</sup> with Balance Board  $n = 7$ ). Other  
167 studies employed custom-designed rehabilitation activities for wheelchair users using  
168 *Microsoft*<sup>®</sup>, *XBox 360*<sup>®</sup>, *Kinect*<sup>TM20</sup> custom-built movement mapping and guidance using  
169 *Microsoft*<sup>®</sup>, *XBox 360*<sup>®</sup>, *Kinect*<sup>TM</sup>,<sup>35</sup> Wobble board with a MTx motion tracker<sup>®</sup> (Xsens  
170 Technologies B.V., Enschede, The Netherlands),<sup>36</sup> a custom-designed closed Kinetic chain  
171 exercise game called WaterBall,<sup>37</sup> a Fitlinxx<sup>®</sup> (FitLinxx, Shelton, CT, USA) system for exercise  
172 tracking and feedback,<sup>38</sup> and a Tectrix<sup>®</sup> Virtual Reality Bike (Cybex International, Inc., Medway,  
173 MA, USA).<sup>39</sup> Although all of the review/discussion articles ( $n = 9$ ) discussed the potential  
174 usefulness of the range of AVG platforms such as *Nintendo Wii*<sup>®</sup>, *Konami Dance Dance*

175 *Revolution*<sup>®</sup> (Konami Digital Entertainment, Inc., El Segundo, CA, USA) , *Microsoft Xbox 360*<sup>®</sup>

176 *Kinect*<sup>™</sup> t Sensor, the main emphasis of the articles was in the usefulness of *Nintendo*<sup>®</sup> *Wii*<sup>™</sup>.

177 Commercial games that were used in the studies include: the *Wii*<sup>®</sup> *Sports* package

178 software (e.g., tennis, baseball, bowling, golf and boxing), the *Wii*<sup>®</sup> *Sports Resort* package

179 software (e.g., swordplay, Frisbee, archery, table tennis, golf, bowling, cycling), the *Wii Fit*<sup>™</sup> or

180 *Wii Fit*<sup>™</sup> *Plus* package software including yoga, strength training, and aerobic games (e.g., hula

181 hoop, basic step, basic run), and balance games (e.g., soccer heading, ski slalom, ski jump, table

182 tilt, tightrope walk, balance bubble, penguin slide), the *Cooking Mama*<sup>®</sup> package software

183 (Cooking Mama Ltd., Office Create, Japan), and the *Konami Dance Dance Revolution*<sup>®</sup> package

184 software.

185 ***Question 3: What psychological benefits have been found to exist when using AVGs as part of***

186 ***musculoskeletal rehabilitation programmes?***

187 The results from the literature review indicated several potential psychological benefits,

188 as well as impairments. These will be presented in three separate subsections: cognitive,

189 emotional and behavioural benefits (impairments will be supplemented where relevant).

190 *Cognitive benefits*

191 Engaging in AVG activities appeared to have a number of perceived cognitive benefits

192 for individuals' cognitive appraisal of the factors associated with the AVG activity itself (i.e.,

193 perceptions about AVG usefulness for musculoskeletal rehabilitation, and enjoyment). In

194 addition, participants' cognitive appraisals of themselves (i.e., intrinsic motivation, perceived

195 positive effects on self) and their injury/impairment (i.e., perception of pain) were commonly

196 reported to the researchers following bouts of AVG activity.

197            *Perceptions about AVG usefulness for musculoskeletal rehabilitation.* Seven studies  
198 reported participants' perceptions of the usefulness of AVG activities for musculoskeletal  
199 rehabilitation, but when obtained, such data was collected via patient self-evaluation reports,  
200 focus groups, and interviews. Positive perceptions of AVG usefulness were reported in five  
201 studies.<sup>24, 25, 32, 40-42</sup> Middlemas et al.<sup>11</sup> proposed that AVGs may be beneficial for sport injury  
202 rehabilitation because they offer both clients and practitioners new ways of thinking about  
203 athletic injury. Thus far only one empirical investigation exists which was conducted with  
204 athletes.<sup>24</sup> The authors of the aforementioned study learned that some of the previously injured  
205 participants felt that it would have been a good addition to use AVGs within their sport injury  
206 rehabilitation. However, the participants (especially those athletes who performed at a high level  
207 in their respective sport) believed that the activities may not have been beneficial simply because  
208 the AVG activities were not strenuous and/or challenging enough.

209            *Enjoyment.* A total of 18 papers indicated that engaging in AVG activities was generally  
210 viewed as enjoyable by the participants.<sup>22-25, 27, 28, 30-32, 34-37, 40, 41, 43-45</sup> Only one study<sup>26</sup> found no  
211 significant differences in participants' perceived enjoyment of AVG activities in comparison to  
212 traditional balance activities. In addition, although Hsu et al.<sup>30</sup> reported that there was increased  
213 participant enjoyment, they indicated that it is likely that the observed increases in enjoyment  
214 were not directly due to the AVG intervention itself, but rather the result of an order effect not  
215 accounted for within the research design (i.e., no counterbalancing of the order of AVG sessions  
216 was employed, with AVG sessions always taking place along with a standard regimen of more  
217 traditional exercise). The authors suggested that the observed increases in enjoyment could have  
218 been due to an overall feeling of enjoyment in response to either kind of physical activity,

219 whether it was owing to the AVG-based activity, or the more traditional form of physical  
220 activity.. Alternatively, the reported enjoyment by the participant may have been an artifact of  
221 participants' anticipation of the repeat sessions of AVG-based exercise that was scheduled for  
222 the future. It is possible that the scale used by the researchers was capturing something other than  
223 activity enjoyment. Furthermore, among the studies reviewed, there is great variation in the data  
224 collection methods for measuring enjoyment. Data were collected through standardized e.g.,  
225 Physical Activity Enjoyment Scale, PACES;<sup>46</sup> and non-standardized (e.g., simple Likert-style  
226 questions such as "how enjoyable was your programme?") questionnaire designs, qualitative  
227 semi-structured/structured interview designs, focus groups, case reports, and participant  
228 observations.

229 *(Intrinsic) motivation.* Closely linked with participant enjoyment, several studies also  
230 measured possible increases in participant motivation that may be due to using AVGs. Di Tore<sup>40</sup>  
231 argued that AVGs have the potential to increase motivation simply because they are fascinating  
232 to the patient, but provided no theoretical or empirical support for their claim. Other studies  
233 suggested that AVGs have the potential to increase individuals' motivation to attend  
234 rehabilitation programmes and participate in related exercises<sup>44</sup> or therapy.<sup>32</sup> Wiemeyer<sup>45</sup>  
235 asserted that AVGs have been found to positively influence motivation.

236 However, based on our review, it appears that the results on the usefulness of AVGs as a  
237 motivational tool during musculoskeletal rehabilitation are inconclusive. These studies that  
238 follow support the contention that AVGs positively influence motivation: Da Gama et al.<sup>35</sup>  
239 found that their participants were highly motivated to complete the AVG exercises. Moreover,  
240 Chang et al.<sup>20</sup> found that motivation in relation to physical rehabilitation increased when AVGs

241 were used as a feedback tool, whilst Manley et al.<sup>24</sup> indicated that AVGs could be useful in  
242 motivating injured athletes to adhere to rehabilitation programmes by facilitating the setting of  
243 goals and targets. Increases in motivation to exercise following AVG interventions were also  
244 reported in three other studies.<sup>21, 34, 43</sup> However, while the review found that AVGs seem to  
245 positively influence motivation (like those studies above), often they were found to have no  
246 effect, and in some cases had deleterious effects, on patient motivation. Such studies revealed no  
247 significant differences in motivation between participants who engaged in AVG interventions  
248 and the control groups.<sup>36, 39</sup> Although reporting increases in motivation amongst participants  
249 who completed the *Wii™* intervention alone, Jacobs et al.<sup>21</sup> reported decreases in intrinsic  
250 motivation to engage in exercise amongst participants who participated in the *Wii* intervention  
251 with a partner, particularly over a period of time. Similarly, both Fung et al.<sup>32</sup> and Manley et  
252 al.<sup>24</sup> found that using AVGs had decrease participants' motivation toward traditional treatment  
253 methods, and as such, may not be beneficial as an adjunct method to traditional rehabilitation  
254 methods. Despite measuring motivation through both the Sports Motivation Scale<sup>47</sup> and Leisure  
255 Motivation Scale<sup>48</sup>, Pasch et al.<sup>19</sup> did not report any clear results from these measures. Based on  
256 the interviews conducted, Pasch et al. concluded that for people who engage in AVGs as a  
257 recreational activity, a participant's motivation to participate in AVGs usually takes one of two  
258 forms: the motivation to achieve (i.e., improve score), or the motivation to relax. Of all the  
259 papers reviewed, only the study by Pasch et al.<sup>19</sup> investigated the possible relationship between  
260 personality traits and a participant's motivation to engage in AVGs. Still, Pasch and colleagues  
261 found no significant relationship between the variables assessed by the Big Five Personality

262 Inventory (i.e., Openness, Conscientiousness, Extraversion, Agreeableness, Neuroticism) and a  
263 patient's motivation to use AVGs.

264         As with enjoyment, the measurement of motivation also varied between studies. On the  
265 whole, the articles included in the present literature review utilized different self-report  
266 questionnaires measuring motivation, as well as structured interviews, and focus groups. In  
267 addition, Chang et al. used the number of correctly executed movements as a measure of  
268 motivation for completing the required rehabilitation exercises.

269         *Perceived positive effects on self.* Another finding which emerged from this literature  
270 review was that engaging in AVG activities may facilitate increases in participants' self-  
271 confidence and self-efficacy. Overall, a total of seven studies<sup>25-27, 29, 34, 41, 45</sup> discussed the  
272 positive impact of AVG activities on individuals' self-confidence and/or self-efficacy (both  
273 terms were often used interchangeably). For example, Coyne<sup>41</sup> presented case reports from  
274 private practice rehabilitation settings, and discovered that patients' self- confidence was affected  
275 in a positive way by the use of AVGs. Additionally, other studies were found to have a positive  
276 effect on patients' self-efficacy;<sup>25, 45</sup> and with paediatric patients, self-esteem AVG interventions  
277 also impacted older adults' self-confidence in dealing with technology in general, and in turn  
278 resulted in a decreased sense of feeling disconnected from the modern world.<sup>34</sup> Similar to  
279 enjoyment and motivation, the measurement of participants' confidence/efficacy also varied,  
280 with the terms "confidence" and "efficacy" often used interchangeably. Those articles that  
281 reported self-confidence and/or self-efficacy results used focus groups, participant comments,  
282 and anecdotal case reports as evidential support.



283           Some of the studies which involved AVGs as a balance training intervention also  
284 measured patients' balance confidence pre- and post-intervention. Interestingly, the results  
285 reported by most of these studies were rather counter-intuitive. Of the four studies directly  
286 reporting balance confidence/efficacy results, only Bainbridge et al.<sup>29</sup> found increases in  
287 participants' balance confidence, although even these results did not reach statistical  
288 significance. Bell et al.,<sup>27</sup> and Kliem and Wiemeyer<sup>26</sup> encountered no significant differences in  
289 balance confidence between AVG users and control groups, or pre- and post-intervention.  
290 Sauter<sup>25</sup> saw that the balance confidence of AVG group participants decreased post intervention.  
291 However, Sauter also observed that to start with, the AVG groups' balance confidence was  
292 noticeably, but not significantly, higher than the control group and other experimental groups,  
293 even after the intervention. Moreover, Brandt and Paniagua<sup>43</sup> found that among older adults in  
294 long-term care facilities, engagement in AVG activities was affected by balance confidence,  
295 since the participants did not like to use AVGs due to their fear of falling out of their chairs.

296           The studies that used AVGs for balance activities used different methods to measure  
297 confidence. Three of the balance confidence studies<sup>25, 29, 31</sup> used the Activities Balance  
298 Confidence Scale.<sup>49</sup> One study<sup>27</sup> applied the Modified Falls Efficacy Scale.<sup>50</sup>, Another study  
299 utilized a structured interview.<sup>43</sup> Kliem and Wiemer<sup>26</sup> reported results from a Likert Scale  
300 question, asking: 'How confident are you to accomplish one leg stand without falling over for  
301 30/45/60/75/90 seconds?'

302           *Perception of, and working through pain.* Of all the studies reviewed, only one study  
303 assessed participants' perceptions of pain.<sup>30</sup> Hsu et al. used the Numeric Rating Scale (NRS),  
304 which is a clinical measure aimed to quantify pain intensity, to assess older adults in long term

305 care facilities. They found no significant decreases in pain intensity levels post-AVG  
306 intervention, although they did find a non-significant reduction of pain bothersomeness (i.e., how  
307 much the pain causes disruption and aggravation to the patient). In addition, case reports from  
308 private practice settings have suggested that using AVGs as a treatment modality has helped  
309 patients work through pain with greater ease.<sup>41</sup>

310 *Other cognitive benefits.* Wiemeyer<sup>45</sup> suggested that AVGs have the potential to  
311 positively impact an individual's perception of control over their situation. However, the present  
312 review found that this was not empirically tested by Wiemeyer, or any other of the other studies.  
313 The use of AVGs has also been shown to have a beneficial impact on participants' overall mental  
314 stimulation amongst older women attending community health services, since the activities are  
315 proposed to stimulate new behaviours and learning in the form of using technology and  
316 gaming.<sup>34</sup>

### 317 *Emotional Benefits*

318 Another emergent psychological construct that has been investigated in the literature  
319 review is the effect of AVGs on individuals' mood and emotional response. The results reported  
320 are equivocal, based on both empirical and anecdotal evidence, and as with the cognitive  
321 constructs reported above, lack consistent methods of data collection.

322 Articles which reported positive changes in mood include Brandt,<sup>43</sup> who found  
323 engagement in AVGs were perceived as "exciting" by participants. Tsai<sup>37</sup> noted that based on  
324 researchers' observations participants became more talkative during the AVG sessions, in  
325 comparison to the non-AVG sessions. Furthermore, according to anecdotal case reports from  
326 private practice settings, practitioners have felt that participants' informal comments and

327 behaviours at the conclusion of AVG sessions have indicated that they were looking forward to  
328 the next session.<sup>41</sup>

329 Other studies<sup>26</sup> found no significant differences in mood states from either pre- and post-  
330 intervention, or between the AVG group and traditional balance training groups. Of the studies  
331 reviewed, two investigated the differences in flow states (i.e., the holistic experience that people  
332 feel when they act with total involvement),<sup>51</sup> between AVG and traditional group participants,  
333 but no significant differences were determined in either study.<sup>26, 33</sup> In a similar way, Annesi and  
334 Mazas<sup>39</sup> found no significant changes in exercise-induced feelings that were reported by  
335 participants in the AVG intervention group. However, the authors did note that those who had  
336 experienced the AVG and recumbent bike experimental conditions felt more rejuvenated after  
337 the combined exercise session than those in the traditional upright exercise bike group.  
338 Anecdotal evidence additionally suggests that participation in AVG activities may also have a  
339 negative effect on individuals' mood, as case reports have suggested that AVGs may have  
340 resulted in increased levels of frustration.<sup>41</sup>

#### 341 *Behavioural Benefits*

342 In relation to the behavioural benefits of AVGs, three main constructs emerged from the  
343 data: (1) activity adherence/compliance, (2) participant engagement, and (3) social relationships.

344 *Activity adherence/compliance.* One of the most commonly investigated and reported  
345 psychological benefits of AVGs were treatment adherence/compliance. A total of four of the  
346 discussion articles<sup>11, 41, 44, 52</sup> proposed that AVGs were an effective means of increasing treatment  
347 adherence and/or compliance. Only Middlemas et al.<sup>11</sup> offered proposals specifically for sport  
348 injury contexts, however these claims were not supported by empirical evidence testing the

349 usefulness of AVGs for that purpose. Additional support via anecdotal case evidence from both  
350 private practice and paediatric hospital settings<sup>41</sup> demonstrated that use of AVGs can be  
351 beneficial in increasing adherence and compliance. In addition, visual feedback from a study  
352 testing the usefulness of *Microsoft XBox 360*<sup>®</sup> *Kinect*<sup>™</sup>-based rehabilitation support systems on  
353 motor rehabilitation guidance and movement correction<sup>35</sup> also indicated that use of AVG  
354 platforms can have a positive effect on treatment adherence. Empirical evidence seems to  
355 suggest that AVGs provide a means of increasing adherence to injury rehabilitation  
356 programmes/exercises. However, there was one exception: the empirical study of Sauter<sup>25</sup>  
357 found no significant differences in adherence between AVG and other experimental groups.  
358 Excluding this study, all other papers which measured this particular variable concluded that  
359 AVGs had a positive effect on adherence and/or compliance with injury rehabilitation  
360 activities.<sup>27, 32, 38, 39</sup>

361 *Participant engagement.* Only three of the studies reviewed explicitly discussed the  
362 benefits of AVGs on participant engagement (i.e., being actively involved in the activity). Tsai  
363 et al.<sup>37</sup> conducted post-intervention interviews and found that not only were participants heavily  
364 engaged in the AVG activities, they also expected to challenge other players during the gaming  
365 session, thus suggesting that AVG activities have the potential to elicit a sense of competition in  
366 participants. By using one of the five-point Likert scale questions, “How engaged were you  
367 during your programme?” Brumels et al.<sup>22</sup> revealed that AVG activities were perceived as more  
368 engaging than traditional balance programme exercises. In contrast, using the same question  
369 (but with a six-point Likert Scale), Kliem and Wiemeyer<sup>26</sup> found no significant difference in  
370 engagement levels between AVG and traditional balance exercise groups.

371           *Social relationships.* Another benefit of AVGs that has been observed in the literature is  
372 improved social relationships. The majority of papers investigating or discussing the use of  
373 AVGs with elderly populations indicated that engaging in AVG activities was enjoyable as it  
374 increased social interaction<sup>27, 34, 37, 41, 43</sup> and bridged the gap between generations.<sup>28, 34, 37</sup> Similar  
375 inferences have also been made for other age groups. For example, Brox et al.<sup>44</sup>, Di Tore<sup>40</sup> and  
376 Wiemeyer<sup>45</sup> have all suggested that AVGs can be very social activities, and as such, have the  
377 potential to increase positive social interaction amongst people of all ages. Support for the above  
378 was found by Fung et al.<sup>32</sup> In their study with occupational and physical therapists working in  
379 hospital settings, participants felt that AVGs had the potential to increase social aspects of  
380 therapy. Brox et al.<sup>44</sup> did however, state that those involved in using AVGs need to be confident  
381 and familiar with the technology first in order to maximize social benefits.

382           Data for the above was typically collected via numerous self-report questionnaires,  
383 participant observations, structured and unstructured post-intervention interviews, focus groups  
384 and anecdotal case reports. Only one study<sup>27</sup> used a previously utilized and validated measure  
385 i.e., Social Provision Scale, SPA.<sup>53</sup> The results of this study using SPA measurements showed no  
386 significant differences in the social provisions between AVGs and other more traditional fall  
387 prevention programme groups.

388           ***Question 4: What psychological theoretical frameworks underpin the use of AVGs in the***  
389 ***context of musculoskeletal rehabilitation?***

390           Of the 30 articles included in the analyses, only one empirical research study explicitly  
391 described the theoretical models that underpinned their planned intervention.<sup>19</sup> Pasch et al.'s<sup>19</sup>  
392 research aims were two-fold: first, to investigate the motivation and gaming experience of four

393 experienced gamers via interviews; and second, to observe and record the movement of ten  
394 graduate student gamers as they were playing the *Wii*<sup>®</sup> *Boxing* game. Pasch et al.<sup>19</sup> provided  
395 brief details of theories they developed that explained individuals' motivation and applied them  
396 to engagement in AVGs. The authors also discussed a number of theories of immersion that  
397 served as potential theoretical frameworks (i.e., concept of flow and theories of immersion) to  
398 explain the gaming experience. However, in the absence of clear theoretical frameworks  
399 explaining motivation and gaming experience, Pasch et al.<sup>19</sup> adopted a Grounded Theory  
400 approach to their data collection and analysis, and concluded that people who play AVGs, do so  
401 for different motivational purposes with differing experiences (i.e., by 'playing the game' to  
402 achieve or by 'simulating the game' to relax).

403 Three of the review/discussion articles<sup>40, 44, 45</sup> considered the importance of theoretical  
404 frameworks for AVG design and development, as well as applied interventions. Brox et al.<sup>44</sup>  
405 argued that AVGs can be used as a means to motivate and persuade older adults to exercise  
406 simply due to them being fun and enjoyable; however, the authors failed to explicitly state which  
407 psychological theory could be used to explain such reactions. Di Tore<sup>40</sup> proposed that when  
408 developing AVGs for the purpose of teaching motor skills, the design and development process  
409 should be guided by psychological models of movement (such as the cognitive and ecological  
410 approach to movement). Wiemeyer<sup>45</sup> argued that any integration of AVGs into prevention,  
411 rehabilitation, and education should be founded on detailed models of effect, rather than based  
412 on the simple premise that AVGs act as a means of enhancing fun.

413 ***Question 5: How can AVGs be used most effectively in the context of musculoskeletal***  
414 ***rehabilitation?***

415           Based on the results from the review, several applied and research recommendations for the  
416 role of AVGs in musculoskeletal rehabilitation were offered for consideration: social and contextual  
417 factors, sociodemographic factors, psychological factors, intervention characteristics, and  
418 intervention practicalities. Each recommendation is discussed in more detail below

419 *Social and contextual factors*

420           A number of social and contextual factors need to be considered when developing and  
421 implementing AVG interventions<sup>33,38</sup>. Specifically, factors such as facility conditions and  
422 accessibility to AVG consoles were identified as important in predicting individuals' intentions of  
423 using such technology<sup>33</sup>, but in what way, that was not clarified by the authors. Annesi<sup>38</sup> also  
424 recommended that if the aim of AVG intervention is to increase adherence by implementing  
425 computerized goal setting and feedback systems to replace professional human interaction,  
426 inclusion of range of social and contextual factors should be taken into account in the planning  
427 process.

428 *Sociodemographic factors*

429           In a similar manner, a range of sociodemographic factors may influence the usefulness of  
430 AVG interventions for musculoskeletal rehabilitation and therapy.<sup>38</sup> For example, gender  
431 differences<sup>25</sup> and personal preferences<sup>34</sup> regarding choice of games, as well as individuals'  
432 performance expectancies<sup>33</sup>, may influence AVG intervention implementation and outcomes. Thus,  
433 the use of AVGs, just like any aspect of the rehabilitation programme/environment, should be  
434 specifically tailored to the needs of the client.

435 *Psychological factors*

436           Of the psychological factors relevant for AVG intervention development and  
437 implementation, it is likely that individuals' motivation to engage in AVG activities will be of  
438 importance.<sup>19</sup> It is also likely that clients' self-efficacy and confidence in terms of their perceived  
439 ability to use AVG technology and complete the required activities successfully will determine  
440 clients' thoughts, feelings and behaviours in response to such interventions. Thus, it is important to  
441 ensure that the target population is familiar with the AVG activities and feels confident about using  
442 them.<sup>11, 41, 44</sup> Such considerations will help to optimise the benefits of the planned intervention while  
443 reducing the risk of incurring harm.

#### 444 *Intervention characteristics*

445           According to the literature, any AVG intervention should be underpinned by relevant theory  
446 (e.g., psychological and mechanical theories of movement).<sup>40</sup> As AVGs have the potential to aid in  
447 the correction of movement,<sup>35</sup> they need to be designed in such a way that allows for realistic  
448 transformation of clients' actions to sensory signals.<sup>45</sup> It has been suggested that commercial  
449 AVG platforms can be used in health care settings for health benefits and social wellbeing.<sup>34</sup>  
450 However, care should be taken when implementing such games with certain populations. For  
451 example, the use of AVGs for individuals with hemiparesis or hand problems could be  
452 detrimental to the client's functionality, furthermore, care should be taken when using AVGs  
453 with those who have experienced seizures,<sup>41</sup> since TV screens have the potential to trigger  
454 further episodes. AVG-based interventions should be motivating and variable,<sup>26</sup> ensuring that  
455 they are fun and entertaining as well as functional.<sup>20</sup> It is also suggested that by incorporating  
456 multiple users to engage in AVG rehabilitation activities simultaneously, such activities can be  
457 made more enjoyable and socially rewarding.<sup>20</sup> However, it is important that practitioners are



458 wary of the impact that competitive game-play can have on a client's progression and ultimate  
459 rehabilitation.<sup>37</sup>

460 *Intervention practicalities*

461 According to Wiemeyer,<sup>45</sup> the appropriate application of AVGs requires the establishment  
462 of a perfect fit of didactics, learning theory, and the respective AVG system. As with any treatment  
463 modality, the primary concern for the effective implementation of an AVG intervention is to ensure  
464 that related activities are specifically targeted and focused on the client's rehabilitation needs.<sup>41, 54</sup>

465 The planned AVG interventions should follow a structured gaming protocol, and additional  
466 time for a warm-up and cool-down should be incorporated into every session.<sup>25</sup> Consideration  
467 must also be given to the appropriate frequency and duration of the intervention,<sup>29, 30</sup> paying  
468 particular attention to the sociodemographic factors outlined above. Thus far, only two studies  
469 have made specific recommendations about the frequency and length of AVG interventions,  
470 suggesting that the appropriate frequency for AVG activities is twice weekly,<sup>25, 32</sup> with a 15-30  
471 minute duration for each session.<sup>32</sup> Again, as with any traditional treatment modality, AVG  
472 interventions should be preceded with appropriate training, both for the clinician/practitioner<sup>11, 41</sup>  
473 and the client.<sup>41</sup> For example, Agmon et al.<sup>28</sup> indicated that to ensure the safe, effective and  
474 independent use of the *Nintendo*<sup>®</sup> *Wii*<sup>™</sup> gaming system by older adults, more than five  
475 supervised training sessions would be required.

476 Middlemas et al.<sup>11</sup> also maintained that when planning on using commercial AVG  
477 platforms during sport injury rehabilitation, clinicians should note that these platforms were  
478 originally intended solely for entertainment. Thus, establishing an appropriate balance between  
479 gaming and learning is essential when utilising such commercially available AVGs.<sup>45</sup> In fact, it has

480 been recommended that such games be used as an adjunct to, rather than a replacement of,  
481 traditional therapy and/or exercise prescription.<sup>11, 32, 44</sup>

## 482 **Discussion**

483 The purpose of this paper was to review existing literature which has examined the potential  
484 psychological benefits of using AVGs within the context of rehabilitation from musculoskeletal  
485 injury, illness, deficiency, or impairment. Whilst a number of interesting and encouraging  
486 findings have been reported in relation to the above study aim, attempts to draw concrete  
487 conclusions and recommendations from the analyses is hampered somewhat by the lack of  
488 consistency among studies in terms of the participant samples recruited, the experimental designs  
489 employed, and the methods of data collection/analysis conducted. For example, given the  
490 differences in physical fitness between traditional sport injury rehabilitation participants and the  
491 more typical populations studied to date (i.e., older adults), it is likely that the results are not  
492 directly comparable, thus reflecting a need to account for important differences between  
493 prospective patient populations. What was surprising from the findings of the reviewed papers  
494 was the notion that AVG interventions had primarily employed the *Nintendo*<sup>®</sup> *Wii*<sup>™</sup>. Not one  
495 study **in which psychological outcomes were measured in a musculoskeletal injury context**  
496 **utilized** the commercially available *Microsoft XBox 360*<sup>®</sup> with *Kinect*<sup>™</sup> Sensor. The use of  
497 *Nintendo*<sup>®</sup> *Wii*<sup>™</sup> has been shown to have various benefits in rehabilitation contexts, particularly  
498 with older adult populations. However, with injured athletes, the movement mechanics detected  
499 and reflected using equipment such as *Microsoft*<sup>®</sup>'s *Kinect*<sup>™</sup> Sensor might serve a better and  
500 more functional purpose for practitioners interested in using AVGs to engage, monitor, and  
501 assess these patients. With the aim to design AVG interventions that allow realistic

502 transformation of patients' actions to sensory signals,<sup>45</sup> it is likely that the technical  
503 specifications of *Kinect*<sup>TM</sup> may be more suited to musculoskeletal sport injury rehabilitation both  
504 functionally (i.e., allows more realistic movement with different treatment aids) and  
505 psychosocially (i.e., allows the creation of more challenging, motivating and engaging  
506 rehabilitation environments). However, further research is clearly warranted in order to verify or  
507 refute this particular contention. When conducting the review of literature, gaming, and human  
508 computer literature was also included in the searches. However, many of these studies were  
509 excluded since did not meet the inclusion criteria and were outside of the scope of this review.  
510 Only studies that investigated psychological outcomes as measured in musculoskeletal injury  
511 contexts were included.

512         From a psychological perspective, which is the main scope of this review, the results  
513 reveal that AVG interventions have the potential to positively affect individuals' cognitive  
514 appraisals of themselves and their rehabilitation situations, and might also provide a number of  
515 emotional and behavioural benefits during musculoskeletal rehabilitation. Consistent with the  
516 Integrated Model of Psychological Response to the Sport Injury and Rehabilitation Process,<sup>10</sup> as  
517 well as the research findings outlined earlier in the Introduction section,<sup>6-9</sup> these psychological  
518 constructs (i.e., cognitive appraisals, emotional, and behavioural responses) can in turn influence  
519 not only the actual rehabilitation process, but also the physical and psychosocial rehabilitation  
520 outcomes. How these constructs manifest, interact and affect the rehabilitation process as a result  
521 of AVG intervention also warrants further investigation.

522         It appears that many of the studies conducted to date lack specific theoretical  
523 frameworks. This can be problematic for a number of reasons: (a) the studies do not provide

524 researchers with a clear description of methodologies used, which (b) limits replicability and  
525 fails to provide opportunities for systematic collection of data, while (c) some of the  
526 psychological constructs measured and reported by patients may not be those initially intended  
527 for assessment. By drawing on the preliminary results from this review, as well as the general  
528 literature related to the psychology of injury rehabilitation, it is proposed that the  
529 Biopsychosocial Model of Sport Injury Rehabilitation<sup>55</sup> (Figure 1) could help provide  
530 researchers and applied practitioners/clinicians with a useful theoretical framework as the basis  
531 for future research and the development of applied AVG interventions. The Biopsychosocial  
532 Model<sup>55</sup> “draws upon approaches increasingly adopted in the healthcare professions which  
533 suggest that health, illness, and injury are best understood in terms of an interaction between  
534 biological, psychological and social factors, rather than in purely biological terms as is  
535 traditional in medicine.”<sup>56</sup> At the core of the model are biological (e.g., metabolism, tissue repair,  
536 sleep), psychological (e.g., personality, cognition, affect and behaviour) and social/contextual  
537 factors (e.g., social networks, life stress, rehabilitation environment), all of which are seen as  
538 having the potential to influence one another. These three factors are also mediated by the  
539 characteristics of injury (e.g., type, cause, severity, and location) and a number of  
540 sociodemographic (e.g., age, gender, socioeconomic status) factors. The model assumes that  
541 biological, psychological, and social/contextual factors also have an effect on the intermediate  
542 biopsychological rehabilitation and recovery outcomes (e.g., range of motion, strength, pain, rate  
543 of recovery). Along with psychological factors, the intermediate biopsychological outcomes also  
544 have a bi-directional relationship with overall injury rehabilitation outcomes (e.g., functional

545 performance, quality of life, treatment satisfaction and readiness to return to optimal  
546 functioning).

547         By creating variability in rehabilitation exercises (i.e., using AVG interventions as a  
548 treatment modality), researchers and applied practitioners are manipulating the rehabilitation  
549 environment (i.e., social/contextual factor). Existing evidence from the current review (albeit  
550 partially limited and conflicting due to inconsistent methodology and design) suggests that AVG  
551 interventions can have a positive impact on patients' cognitions, affective responses and  
552 behaviours (i.e., psychological factors). Evidence has also suggested that various intermediate  
553 biopsychological and injury rehabilitation outcomes can be affected by AVG interventions;  
554 although, thus far it appears that differences in functional outcome measures between AVG and  
555 traditional balance rehabilitation activities have not been reported.<sup>26, 27, 30, 31</sup> The current results  
556 also indicate that a range of sociodemographic factors (e.g., age, physical health) may influence  
557 successful AVG intervention implementation. Furthermore, it is likely that injury characteristics  
558 and biological factors (e.g., individuals with hemiparesis or hand problems) will play a role in  
559 the planning, design and overall usefulness of AVG interventions in injury rehabilitation  
560 contexts.<sup>41</sup> By using the Biopsychosocial Model as a framework, both researchers and applied  
561 practitioners/clinicians can provide a clear structure and robust foundation for their interventions.  
562 Through the Biopsychosocial Model, a number of factors could be tested and/or controlled for  
563 simultaneously, thus providing an integrated approach to the interventions. This could then be  
564 coupled with a framework that forms the basis for different phases of rehabilitation,<sup>57</sup> as well as  
565 relevant theories underpinning the chosen constructs to be measured e.g., adherence;<sup>58</sup> or mood;

566 <sup>59, 60</sup> thus making any proposed interventions not only structured and easy to replicate and  
567 monitor, but also purposeful and grounded in appropriate theory and evidence.

### 568 **Conclusions**

569 By conducting a review of the relevant extant literature, the purpose of this paper was to  
570 examine the extent to which AVGs provide psychological benefits for patients undergoing  
571 rehabilitation from musculoskeletal injury, deficiency, or impairment. The research to date appears  
572 to lack clear theoretical frameworks, and consistent methodologies; as such, the results are  
573 inconsistent and contradictory. However, the initial evidence is encouraging. These studies indicate  
574 that AVG interventions have been effective in facilitating short-term psychological (and in turn,  
575 physical) benefits to clients participating in a variety of rehabilitation programmes. Despite this,  
576 the long-term effects are still unknown,<sup>45</sup> and the effectiveness of AVG interventions requires  
577 additional investigation utilizing appropriate research designs, measurement items, and outcome  
578 variables.<sup>41</sup> In conclusion, it is suggested that the Biopsychosocial Model of Sport Injury  
579 Rehabilitation<sup>55</sup> could be a useful framework for future research and applied intervention  
580 designs.

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