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Objectively evaluated physical activity among individuals following anterior cruciate ligament reconstruction: a systematic review and meta-analysis

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ABSTRACT

Objective To compare time spent in moderate-to-vigorous physical activity (MVPA) per week, MVPA per day, and steps per day between individuals that were subjected to the anterior cruciate ligament reconstruction (ACLR) and healthy control group.

Design Systematic review and meta-analysis of observational studies.

Data sources Web of Science, Scopus, and PubMed have been comprehensively searched to identify relevant investigations.

Eligibility criteria for selecting studies An observational research that objectively evaluated physical activity among respondents with a history of ACLR.

Results Of 302 records, a total of 12 studies fulfilled the eligibility criteria. Four hundred and forty-three participants underwent the ACLR, 153 men and 290 women. The mean time between anterior cruciate ligament (ACL) surgery and evaluation of analysed outcomes was 34.8 months. The main findings demonstrated that the ACLR group spent less time in weekly MVPA (standardised mean differences (SMD)=−0.43 (95% CI −0.66 to −0.20); mean = −55.86 min (95% CI −86.45 to −25.27); p=0.0003; τ^2=0.00), in daily MVPA (SMD=−0.51 95% CI −0.76 to −0.26]; mean = −15.59 min (95% CI −22.93 to −8.25); p<0.0001; τ^2=0.00), and they had fewer daily steps (SMD=−0.60 95% CI −0.90 to −0.30); mean = −1724.39 steps (95% CI −2552.27 to −896.50); p<0.0001; τ^2=0.00) relative to their non-injured counterparts. Additionally, available investigations indicated that individuals with a history of ACLR participated in 316.8 min of MVPA per week, 67 min in MVPA per day, and 8337 steps per day.

Conclusion Long-term after ACLR, participants undergoing ACL surgery were less physically active compared with their non-injured peers, and they did not satisfy recommendations regarding steps per day.

PROSPERO registration number CRD42023431991

WHAT IS ALREADY KNOWN

⇒ Anterior cruciate ligament injury is a frequent knee injury among the physically active population.
⇒ Numerous self-reported physical activity assessments examined the influence of anterior cruciate ligament reconstruction (ACLR) on the physical activity participation of respondents.
⇒ The influence of ACLR on objectively evaluated physical activity parameters still needs to be comprehensively summarised.

WHAT ARE THE NEW FINDINGS

⇒ Individuals who were subjected to the ACLR engaged in substantially less weekly moderate-to-vigorous physical activity (MVPA), daily MVPA and the number of daily steps compared with the healthy matched controls.
⇒ Literature reported that respondents with a history of ACLR spent approximately 316.8 min per week in MVPA, 67 min in daily MVPA and participated in 8337 steps per day.
⇒ Taking into account that ACLR harmfully affected the physical activity variables of the participants, specific exercise programmes are necessary to improve their health.

INTRODUCTION

Anterior cruciate ligament (ACL) injury is considered one of the most explored orthopaedic conditions in the field of sports medicine and sports traumatology.[1] ACL also has quite a relevant role in the stabilisation and kinematics of the knee joint.[2] Moreover, a robust body of evidence indicates that ACL injury is a very common knee injury among physically active individuals.[3 4] It has been reported that approximately 250 000 ACL injuries occur per year in the USA.[1 5 6] Most importantly, the authors emphasised that more than half of the population that experienced ACL injury underwent ACL reconstruction (ACLR). Furthermore, ACLR was linked with health-related quality of life,[7] knee-specific functions[8] and fear of reinjury.[8] More precisely, surgery of ACL induced deterioration of health-related quality of life.[7] Similarly, individuals with a history of ACLR had significantly lower scores referring to self-reported knee function, estimated with Knee Osteoarthritis and Injury Outcome Score,

and higher fear of reinjury compared with the healthy matched controls.[8] According to Caspersen *et al*,[9] 'physical activity is defined as any bodily movement produced by skeletal muscles that result in energy expenditure'. Participation in different types of physical exercise is crucial to maintaining and improving a healthy lifestyle. There is abundant evidence relating to the benefits elicited by regular physical activity.[10–12] For instance, regular physical exercise correlated with a decreased risk for certain chronic medical conditions, such as cardiovascular diseases, hypertension, type 2 diabetes and breast cancer.[10] Moreover, a strong negative relationship between obesity and the level of physical engagement has also been documented.[11] In addition, physical exercise positively affected various mental health parameters, including symptoms of anxiety, depression and stress states.[12] In contrast, physical inactivity was a substantial financial burden, which refers to direct medical care and productivity loss, causing costs of US$93.92 billion for American adults.[13] At last, it is noteworthy to highlight that the risk of musculoskeletal injuries rises with increased levels of physical exercise.[14 15] Objective evaluation of physical activity, including variables such as moderate-to-vigorous physical activity (MVPA) per week, MVPA per day and steps per day, was most commonly performed using accelerometers and pedometers.[16 17] Literature emphasised several advantages of objectively quantified physical activity compared with the self-reported assessment, such as reduced bias in reporting results and improved understanding of the relationship between exercise and health.[18] Currently, a minimum of 150 min of weekly MVPA is recommended for adults aged 18–65.[19] To satisfy these guidelines, a person should engage in numerous types of physical exercise involving brisk walking, playing badminton, dancing or jogging, cycling and participation in some of the team sports.[20] Additionally, 10 000 daily steps are considered indispensable to enhancing health outcomes.[21] Most importantly, scientific evidence suggested that less than 10% of the US population meets physical activity recommendations according to accelerometry.[22] To date, several systematic reviews and meta-analyses addressed objectively measured physical activity and lower extremity injuries, including musculoskeletal injuries,[23–25] lower limb arthroplasty[26 27] or fractures[28] and hip or knee osteoarthritis.[29] There is fairly convincing evidence that individuals with lower extremity injuries have been less physically active relative to the control group and that they did not fulfil previously highlighted guidelines. For example, respondents with musculoskeletal injuries of the lower extremities spent considerably less time in MVPA per week and MVPA per day and had fewer daily steps than their non-injured counterparts.[23] In addition, the majority of the persons with hip and knee osteoarthritis did not satisfy physical activity guidelines pertaining to the weekly time engaged in MVPA and steps per day.[29] Likewise, solely 1% of participants with hip fractures achieved physical exercise recommendations 7 months after the injury.[28] Overall, the presented body of knowledge indicated that all specified lower limb injuries negatively impacted objectively evaluated physical activity parameters. Finally, as previously emphasised, the level of physical activity engagement is linked with countless health parameters. Namely, exploring objectively quantified physical activity should have relevant health implications for the ACLR population. Therefore, it is necessary to summarise available literature relating to the ACLR and objectively estimated physical activity variables. The primary purpose of this investigation was to compare individuals with a history of ACLR and a healthy control group regarding time spent in MVPA per week, MVPA per day and participation in steps per day. It was hypothesised that the ACLR group would be significantly less physically active in all relevant parameters than the non-injured respondents. The secondary objective was to examine whether the individuals with ACLR fulfilled the recommendations of 150 min of MVPA per week and 10 000 steps per day. The authors hypothesised that respondents who were subjected to the surgery of the ACL would not meet the stated guidelines.

METHODS

Study design

This investigation was carried out in line with all requirements available in the Preferred Reporting Items for Systematic Review and Meta-Analyses (PRISMA) statement.[30] Of note, the PRISMA checklist is provided in the online supplemental material. Registration of the research protocol has been conducted via the International Prospective Register of Systematic Reviews (PROSPERO). There were no amendments regarding protocol registration.

Search strategy and study selection process

A comprehensive search of the three electronic databases, including Web of Science, Scopus and PubMed, has been performed from inception to 10 June 2023, to identify relevant articles. The following keywords and a Boolean search syntax with the operators 'AND' and 'OR' were implemented: ("physical activity" OR "physical exercise" OR "accelerometers" OR "pedometers" OR "moderate-to-vigorous physical activity" OR "steps per day") AND ("anterior cruciate ligament" OR "anterior cruciate ligament reconstruction" OR "ACL injury" OR "knee injury" OR "lower extremity injuries") (online supplemental file 2). Additional studies have been identified through Google Scholar search and manual check of reference lists of each relevant research. Two independent reviewers (RR and TT) completed the literature search and selection process, which involved database searches, review of titles and abstracts, and analysis of full-text records. Potential disagreements among reviewers were resolved via the discussion until a consensus was reached. However, if it was not possible to reach a consensus between reviewers, the first investigator (MM) was consulted for clarification.

Eligibility criteria

Investigations have been included if: (1) study design was observational; (2) respondents experienced ACL injury and were subjected to the ACLR; (3) physical activity was measured objectively, using accelerometers, pedometers, etc and (4) outcomes estimated referred to the MVPA per week, MVPA per day and daily steps. On the other hand, exclusion criteria were (1) self-reported assessment of physical activity using certain questionnaires; (2) lower extremity injuries pertained to the hip, ankle, or other knee injuries; and (3) Non-English studies. Finally, abstracts, systematic reviews with meta-analysis, not-peer-reviewed journal articles, doctoral theses, case reports, editorials, and expert opinions were not deemed suitable for inclusion.

Data extraction

Two reviewers (AC and AB) independently retrieved data from all of the studies using a Microsoft Excel template. Extracted data can be divided into the following categories: (1) authors and year of articles publication; (2) study design and presence of a control group; (3) respondents' characteristics, such as sample size, gender, mean age, body mass index, graft type applied, and time since surgery expressed in months; (4) measuring tools implemented for quantification of physical activity as well as the number of days during which relevant variables were evaluated; and (5) parameters assessed related to the MVPA per week, MVPA per day and steps per day (online supplemental file 1). Considering that all data have been available in the studies, there was no need to contact the corresponding authors via email. Nonetheless, PlotDigitizer online software (www.plotdigitizer.com) was employed to extract data from the figures in several investigations. Regarding discrepancies between reviewers, the first investigator (MM) decided which of the data should be extracted and presented in the manuscript.

Study risk of bias assessment

The methodological index for non-randomised studies (MINORS) was employed for the quality evaluation of studies involved in the presented systematic review and meta-analysis.[31] The MINORS assess 8 and 12 aspects related to non-comparative and comparative research, respectively. Each of the items is given a score of 0 (not reported), 1 (reported but inadequate) and 2 (reported and adequate). Hence, the maximum overall score for non-comparative studies was 16 and 24 for comparative investigations. In terms of non-comparative studies, the overall score was interpreted according to the previously established categories: 0 to 4 indicated very low quality; 5 to 8, low quality; 9 to 12, moderate quality and 13 to 16 indicated high quality.[32] Additionally, in the studies with a control group, the overall score was categorised in line with the following criteria: 0 to 6 indicated very low quality; 7 to 12, low quality; 13 to 18, moderate quality and 19 to 24 indicated high quality.[32] Two independent reviewers (ZG and NM) rated studies, while all inconsistencies among them were clarified following the consultation with the first investigator (MM).

Data analysis

Meta-analysis was conducted using Review Manager V.5.4 (The Nordic Cochrane Centre, The Cochrane Collaboration, Copenhagen, Denmark). Statistical analysis was carried out separately for variables of MVPA per week, MVPA per day and steps per day if a minimum of three or more studies evaluated these parameters. In each of the analyses, a random-effect model with the Hartung-Knapp-Sidik-Jonkman adjustment has been applied. Standardised mean differences (SMD) between groups as well as 95% CI were calculated and interpreted as trivial, small, moderate or large for values SMD<0.2, 0.2≤SMD<0.5, 0.5≤SMD<0.8 and SMD≥0.8, respectively.[33] Heterogeneity levels among studies were estimated with τ^2, and considered as low (τ^2<0.04), moderate (τ^2<0.09) and large (τ^2>0.16).[34] Differences between participants who underwent ACLR and healthy controls were deemed statistically significant if the p value was<0.05.

Equality, diversity and inclusion statement

In all of the available investigations, there were no restrictions regarding gender, race, ethnicity, socioeconomic status and representation from marginalised groups. The authors from European universities, whose research area refers to sports science and medicine, participated in this study. There were doctoral students, junior and senior scientists.

RESULTS

Literature search results

Initially, a thorough search of the three electronic databases yielded a total of 696 records. The titles and abstracts of 302 studies have been reviewed following the elimination of 394 duplicates. All duplicates were eliminated using Zotero software. Thereafter, 232 trials were removed, and 70 full-text articles were assessed for eligibility. At last, reviewers (RR and TT) excluded 59 records with reasons (online supplemental file 3), and 12 papers, involving one additional identified throughout citation searching, have been presented in the final analysis of this literature review with meta-analysis. Of note, qualitative and quantitative analyses were implemented for 12 and 7 investigations, respectively. Figure 1 depicts a complete overview of the literature selection process.

Study characteristics

All studies published between 2017 and 2022 (table 1). More specifically, there were 12 observational investigations, and the presence of a control group was recorded in seven articles.[35–41] Regarding respondents' characteristics, 443 individuals were subjected to ACL surgery, 153 men and 290 women, with a mean age of 21.6 years. Additionally, there were 265 healthy controls, out of 79 were men and 186 women, aged 20.4 years. Furthermore, the average body mass index of the participants

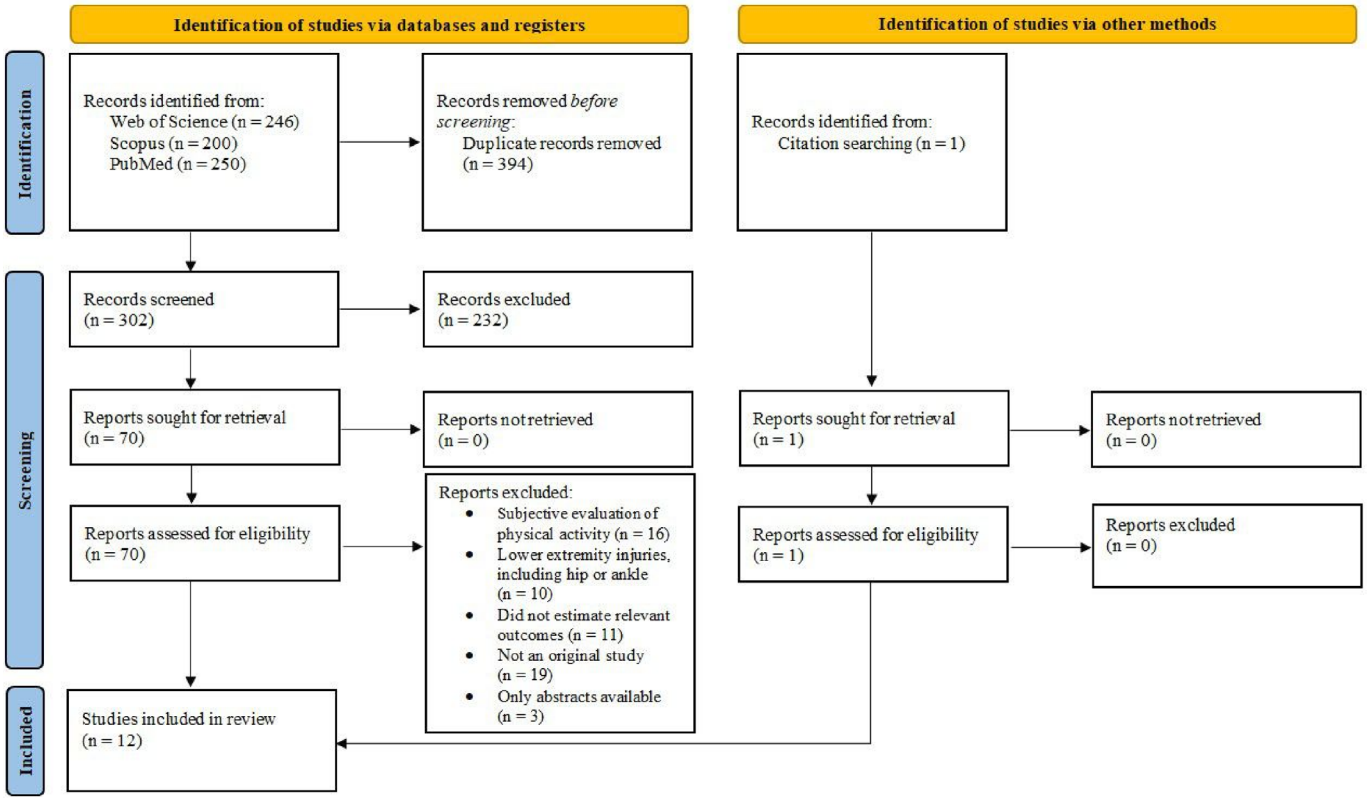

Figure 1 PRISMA flow diagram demonstrates the entire process of the research selection. PRISMA, Preferred Reporting Items for Systematic Reviews and Meta-Analyses.

with a history of ACLR was 24.7 kg/m^2 compared with the 23.4 kg/m^2 of their healthy counterparts. Bone-tendon-bone and hamstring autografts have been most commonly employed concerning the source of graft types. In addition, quadriceps autografts, patellar tendon, semitendinosus autografts and allografts were also applied. Available literature reported that the time between surgery and objective evaluation of the examined variables was approximately 34.8 months. ActiGraph wGT3X-BT accelerometer quantified MVPA per week, MVPA per day and steps per day in the majority of the involved studies. Additionally, the ActiGraph GT9X link accelerometer and Charge 3 physical activity[42] monitor also estimated relevant parameters. Only one research used a pedometer to assess engagement in daily steps in individuals who underwent ACLR.[43] In 10[35 37–41 43–46] out of 12 investigations, MVPA per week, MVPA per day and the count of daily steps were estimated over 7 days. However, the mentioned parameters have also been evaluated during the 13[36] and 28 days.[42] More details regarding the measuring instruments applied and the number of days during that examined variables were evaluated are given in table 2.

Between-group differences and the average values of relevant physical activity parameters in individuals that underwent ACLR

Figure 2, figure 3 and figure 4 illustrate between-group differences in variables MVPA per week, MVPA per day and daily steps, respectively. ACLR group spent substantially less time in weekly MVPA compared with the healthy matched controls (SMD=−0.43 (95% CI −0.66 to −0.20); mean=−55.86 min (95% CI −86.45 to −25.27); p=0.0003; τ^2=0.00). Similarly, the meta-analysis revealed statistically significant differences among ACLR and control groups regarding MVPA per day. Individuals undergoing to the ACL surgery spent considerably less time in daily MVPA relative to the non-injured participants (SMD=−0.51 (95% CI −0.76 to −0.26); mean=−15.59 min (95% CI −22.93 to −8.25); p<0.0001; τ^2=0.00). At last, the ACLR group engaged in significantly fewer daily steps compared with the healthy control group (SMD=−0.60 95% CI −0.90 to −0.30); mean=−1724.39 steps (95% CI −2552.27 to −896.50); p<0.0001; τ^2=0.00). Funnel plots are available as supplementary material (online supplemental files 4–6). Based on the data provided in five studies,[37–39 41 46] respondents with ACLR spent approximately 316.8 min per week in MVPA. Furthermore, participation in daily MVPA was also analysed in five investigations.[35 36 40 45 46] Studies reported that individuals with a history of ACLR spent, on average, 67 min in MVPA per day. According to the data given in eight research,[35 39 41–46] individuals who were subjected to the ACLR had 8337 daily steps. Table 2 displays the results provided in each of the studies with respect to the MVPA per day, MVPA per week, and steps per day.

Table 1 Study design and demographic parameters of respondents

Authors and year	Study design	Control group	Sample description	Gender	Mean age (years)	Body mass index (kg/m²)	Graft source	Time since surgery (months)
Baez *et al*[43]	Modified cross-sectional	No	40 individuals with a history of unilateral ACLR	Male=15; Female=25	24.3±4.2	25.3±2.8	NA	68.4±15.6
Barchek *et al*[44]	Modified cross-sectional	No	19 respondents with unilateral ACLR	Male=6; Female=13	22.9±3.2	24.3±4.5	NA	63.6±13.7
Bell *et al*[35]	Cross-sectional	Yes	33 individuals with a history of primary unilateral or bilateral ACLR and 33 healthy controls	ACLR group: Male=11; Female=22 CG: Male=11; Female=22	ACLR group: 20.3±1.8 CG: 20.8±1.6	ACLR group: 23.7±3.2 CG: 23.3±3.0	BTB, hamstring autograft, and allograft	27.8±17.5
Davis-Wilson *et al*[45]	Cross-sectional	No	66 participants that were subjected to primary ACLR	Male=36; Female=30	22.1±4.5	24.2±2.9	BTB, semitendinosus autograft, quadriceps autograft, and allograft	28.1±33.4
Ezzat *et al*[36]	Cohort	Yes	51 athletes with primary unilateral ACLR and their 51 healthy peers	Female	ACLR group: 18.3±2.2 CG: 18.1±2.0	ACLR group: 23.3±3.9 CG: 22.6±2.5	NA	13.2±14.6
Kuenze et al[37]	Observational	Yes	31 respondents that underwent primary unilateral or bilateral ACLR and 31 participants without a history of ACLR	ACLR group: Male=8; Female=23 CG: Male=8; Female=23	ACLR group: 19.8±1.4 CG: 20.6±1.7	ACLR group: 23.7±3.0 CG: 23.2±3.0	BTB and hamstring autograft	26.8±15.8
Kuenze et al[38]	Cross-sectional	Yes	59 individuals with primary unilateral or bilateral ACLR and 55 healthy control respondents	ACLR group: Male=25; Female=34 CG: Male=22; Female=33	ACLR group: 20.5±2.4 CG: 20.5±1.8	ACLR group: 24.2±2.9 CG: 23.9±2.9	BTB, hamstring autograft, and allograft	29.0±17.3
Kuenze *et al*[46]	Cross-sectional	No	23 adults that underwent primary unilateral ACLR	Male=9; Female=14	22.5±5.0	26.6±4.1	BTB, hamstring autograft, and allograft	8.2±2.1
Kuenze *et al*[42]	Observational	No	12 individuals that were subjected to primary unilateral ACLR	Male=2; Female=10	22.0±3.0	23.5±2.9	Hamstring autograft and patellar tendon	56.0±36.3
Lisee *et al*[39]	Cross-sectional	Yes	57 respondents with a history of primary unilateral ACLR and their 42 non-injured counterparts	ACLR group: Male=23; Female=34 CG: Male=20; Female=22	ACLR group: 20.9±3.2 CG: 20.7±1.7	ACLR group: 25.3±3.1 CG: 25.4±3.3	NA	28.7±17.7
Toomy *et al*[40]	Historical cohort	Yes	25 out of 42 individuals experienced ACLR and 43 healthy controls	ACLR group: Male=18; Female=24 CG: Male=18; Female=25	ACLR group: 23.7±2.9 CG: NA	ACLR group; 25.7±5.1 CG: NA	NA	NA
Triplett and Kuenze[41]	Cross-sectional	Yes	10 participants with a history of unilateral ACLR and 10 noninjured controls	Female	ACLR group: 21.4±3.8 CG: 21.9±3.1	ACLR group: 26.1±3.8 CG: 21.8±2.5	BTB, hamstring autograft, and quadriceps autograft	33.0±18.3

Values of variables mean age (years), body mass index (kg/m²), and time since surgery (months) are expressed as mean and SD.
ACLR, anterior cruciate ligament reconstruction; BTB, bone tendon bone; CG, control group; NA, not applicable.

Table 2 Parameters of objectively measured physical activity of individuals that underwent ACLR

Authors and year	Measuring instrument	Data collection (days)	MVPA per week	MVPA per day	Steps per day
Baez *et al*[43]	Pedometer	7	NA	NA	8,657±2467
Barchek *et al*[44]	ActiGraph GT9X link accelerometer	7	NA	NA	11,238±5668
Bell *et al*[35]	ActiGraph wGT3X-BT accelerometer	7	NA	79.37±23.95	8,158±2780
Davis-Wilson *et al*[45]	ActiGraph GT9X link triaxial accelerometer	7	NA	69±26	8,602±2466
Ezzat *et al*[36]	ActiGraph wGT3X-BT accelerometer	13	NA	48.65±29.11	NA
Kuenze et al[37]	ActiGraph wGT3X-BT accelerometer	7	553±175	NA	NA
Kuenze et al[38]	ActiGraph wGT3X-BT accelerometer	7	147±111	NA	NA
Kuenze *et al*[46]	ActiGraph wGT3X-BT accelerometer or GT9X link monitor	7	341±153	49±22	8,365±2294
Kuenze *et al*[42]	Charge 3 physical activity monitor	28	NA	NA	8,812±1068
Lisee *et al*[39]	ActiGraph wGT3X-BT accelerometer or GT9X link monitor	7	176±117	NA	8,442±2663
Toomy *et al*[40]	Actigraph wGT3x-BT accelerometer	7	NA	60.65±21.66	NA
Triplett and Kuenze[41]	ActiGraph link accelerometer	7	367±226	NA	6,650±3227

Values of variables MVPA per week, MVPA per day and steps per day are expressed as mean and SD.
ACLR, anterior cruciate ligament reconstruction; MVPA, moderate-to-vigorous physical activity; NA, not applicable.

Risk of bias in studies

There were five non-comparative[42–46] and seven comparative studies.[35–41] Concerning research without a control group, the range of overall quality score was between 11 and 14, while the mean overall quality score was 12.6, indicating high methodological quality. Analogous, for studies with a healthy control group, the range of overall quality score was between 16 and 22. The mean overall quality score was 18.7; therefore, the methodological quality of comparative investigations was also defined as high. The lowest rated have been items such as unbiased assessment of the study endpoint, loss to follow-up of less than 5% and prospective calculation of the study size. The complete evaluation of the studies, included the presented systematic review and meta-analysis, is provided in table 3.

DISCUSSION

Overall summary of findings

To the best of the authors' knowledge, this is the first research that summarised currently available scientific evidence that referred to the objectively measured physical activity among individuals who were subjected to ACL surgery. In line with the first hypothesis, respondents with a history of ACLR have been markedly less physically active compared with the healthy control group. More precisely, the ACLR group spent significantly less time in weekly MVPA, and daily MVPA, and had noticeably fewer steps per day. Likewise, as was hypothesised, respondents who underwent ACLR had 8337 steps per day, which is substantially lower than the recommended 10 000 steps per day. On the other hand, contrary to the second hypothesis, individuals with a history of ACLR were engaged in 316.8 min per week in MVPA and 67 min per day in MVPA, markedly exceeding already highlighted recommendations.

Comparisons with the self-reported assessment of physical activity and findings related to the other lower extremity injuries

In terms of subjective evaluation of physical activity after ACLR, the Tegner activity scale,[47–53] Marx activity scale,[54–56] International Physical Activity Questionnaire[57] and Minnesota Leisure-time Physical Activity Questionnaire,[58] were most commonly implemented. The results obtained in studies in which physical activity was assessed using specified questionnaires are inconsistent with the evidence provided in the presented research. Specifically, based on their findings, it is apparent that ACLR did not harmfully affect the physical activity participation of respondents. For instance, no differences between the ACLR group and healthy matched controls have been observed when the level of physical activity was estimated with the Tegner activity scale or Marx activity scale[8] as well as with International Physical Activity Questionnaire.[57] Similarly, using the Tegner activity scale, there were no differences in five[48 50–53] of seven[47–53] investigations relating to the comparisons of periods before and

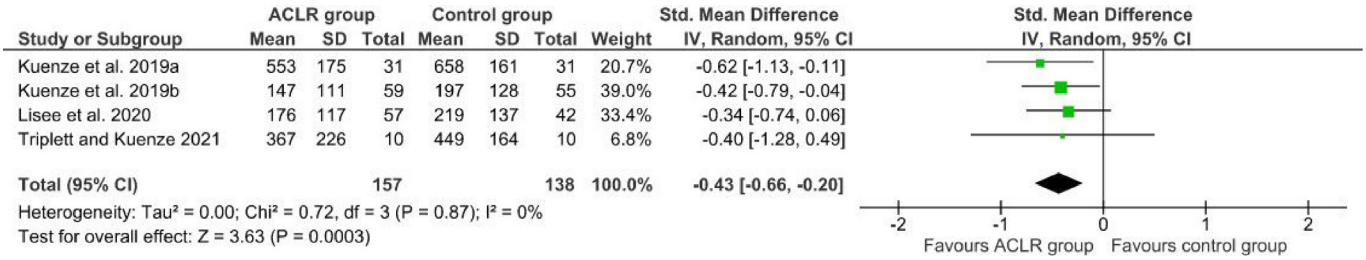

Figure 2 Differences between ACLR group and healthy controls in variable MVPA per week. ACLR, anterior cruciate ligament reconstruction; MVPA, moderate-to-vigorous physical activity.

following surgery. In contrast, in several studies, Marx's activity scale revealed deterioration of the level of physical engagement in individuals who were subjected to the ACLR.[54 56] The Multicenter Orthopaedic Outcomes Network (MOON) Knee Group[54] emphasised that physical activity significantly declined 6 and 10 years after the surgery relative to the baseline values. Overall, taking into account the incompatibility of the results obtained in this research and evidence referred to the self-reported assessment of physical activity in participants with a history of ACLR, future studies need to be more oriented towards objective quantification of physical activity in this population. Moreover, besides the previously mentioned advantages of objective over traditional physical activity assessment, accelerometers offer a detailed evaluation of exercise intensity, and they also eliminate the possibility of recall error.[35] Thus, researchers whose expertise is related to sports science, sports medicine and sports traumatology must be aware of the advantages of objective evaluation of physical exercise, and they should conduct additional examinations to verify the results obtained in this study. The findings of the presented literature review are supported by the studies that examined objectively measured physical exercise and lower extremity injuries, such as patellofemoral pain,[59] hip pain,[60] knee osteoarthritis,[61 62] chronic ankle instability[63] and lower limb fractures.[64] First, individuals with chronic ankle instability[63] and lower limb fracture[64] spent less time in MVPA per week and MVPA per day, respectively, compared with their non-injured counterparts. Second, respondents with patellofemoral pain engaged in fewer daily steps relative to the healthy control group.[59] Analogous, the number of steps per day was substantially below the suggested guidelines in persons with knee osteoarthritis.[62] Third, contrary to the findings of this systematic review and meta-analysis, participants with knee osteoarthritis did not fulfil the recommendations of 150 min of MVPA per week.[61] However, the mean age of respondents was 65.1 years, and this factor is likely responsible for the stated inconsistency. Overall, as well as all mentioned lower extremity injuries, ACLR negatively impacted objectively evaluated physical activity variables. Therefore, physical activity interventions appear indispensable for this population in order to prevent exacerbation of health parameters.

Clinical relevance of the results

The findings of this study indicated that individuals with a history of ACLR doubly exceeded physical activity guidelines regarding time spent in MVPA per week. Nevertheless, the results obtained highlighted that respondents undergoing ACLR had 8337 daily steps, which is considerably below previously emphasised recommendations. Interestingly, several investigations also documented a positive association between the count of steps per day and knee joint health[65 66] as well as an inverse relationship between the count of daily steps and the incidence of cardiovascular events or type 2 diabetes.[67] Most importantly, the main findings unambiguously demonstrated that individuals who experienced surgery of ACL have been noticeably less physically active in terms of all the examined variables compared with the healthy matched controls. Hence, since ACLR negatively affected physical activity participation, various additional health implications must be taken into account, including the protective effects of exercise concerning premature death[68] and its inverse associations with all-cause mortality.[10] Experts in the fields of sport and exercise science and medical workers need to stimulate engagement in different types of physical activity of the population with a history of

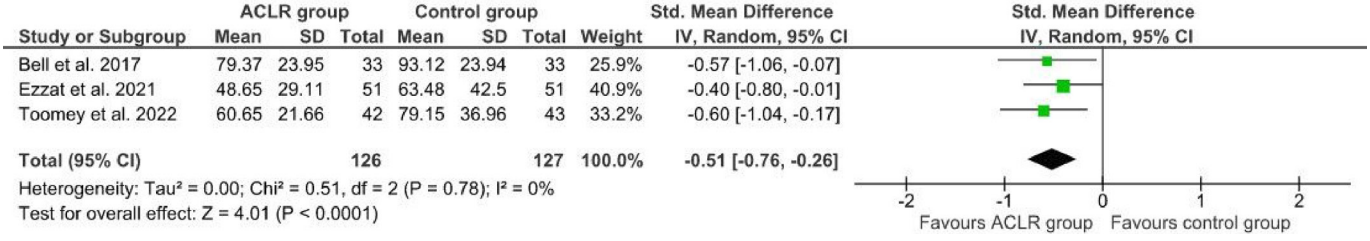

Figure 3 Differences between ACLR group and healthy controls in variable MVPA per day. ACLR, anterior cruciate ligament reconstruction; MVPA, moderate-to-vigorous physical activity.

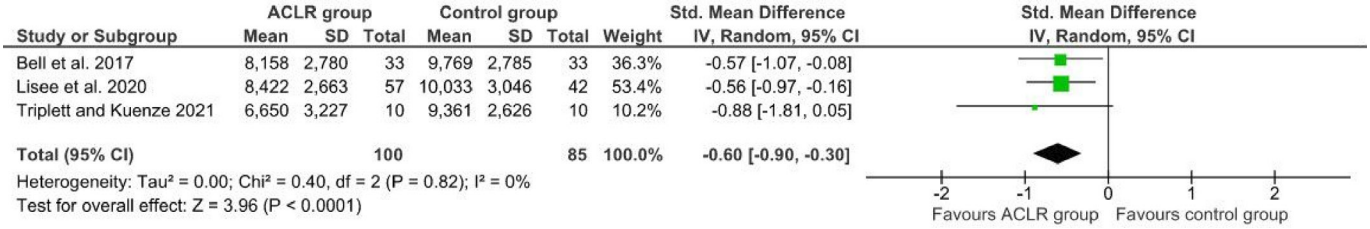

Figure 4 Differences between ACLR group and healthy controls in variable steps per day. ACLR, anterior cruciate ligament reconstruction.

ACLR due to already mentioned health consequences induced by the insufficient amount of physical exercise. More precisely, the following examinations should focus on creating specific exercise programmes for this population regarding exercise intensity, volume and frequency, accounting for the impaired function of their knees.

Strengths and limitations

There are several strengths of this systematic review with meta-analysis that is necessary to highlight. The majority of the included studies have been published within the last 3 or 4 years. Thus, the evidence provided in the presented investigation should be considered rather innovative and current. Moreover, the methodological quality of both non-comparative and comparative studies was high, which is truly rare for a literature review from the area of sports science and medicine. At last, the main findings have robust practical implications that are very useful for experts in the field of sports and exercise science as well as for orthopaedists and other medical workers. Conversely, certain crucial limitations must be acknowledged and taken into account during the interpretation of the results obtained. A restricted number of articles compared examined parameters between the ACLR group and their healthy counterparts. Therefore, more studies with the control group seem necessary to verify these results. Available research most commonly addressed female individuals; namely, additional studies should evaluate men who were subjected to the ACLR. In addition, values of all the relevant parameters before the surgery were not accessible in the respondents with ACLR. Hence, in future studies, it would be useful to objectively evaluate physical activity before the surgery and compare it with the values obtained after ACLR. It should also be noted that the average time between the surgery and assessment of physical activity variables was less than 3 years, and more long-term follow-up studies are warranted to verify the crucial findings from this systematic review. Finally, considering that a recent literature[69] recommended a minimum of 8000 steps per day regarding health benefits, findings related to

Table 3 Quality assessment of the included investigations

Authors and year	1	2	3	4	5	6	7	8	9	10	11	12	Total score
Baez *et al*[43]	2	2	2	1	1	2	2	0	NA	NA	NA	NA	12/16
Barchek *et al*[44]	2	2	2	2	1	2	2	1	NA	NA	NA	NA	14/16
Bell *et al*[35]	2	2	2	2	0	2	2	2	2	1	1	2	20/24
Davis-Wilson *et al*[45]	2	2	1	2	1	2	1	2	NA	NA	NA	NA	13/16
Ezzat *et al*[36]	2	2	2	2	2	2	2	1	2	1	2	2	22/24
Kuenze *et al*[37]	1	2	2	2	0	2	2	2	2	2	2	1	20/24
Kuenze *et al*[38]	2	2	1	2	0	2	1	1	2	1	2	2	18/24
Kuenze *et al*[46]	2	2	2	2	0	2	2	1	NA	NA	NA	NA	13/16
Kuenze *et al*[42]	2	2	2	1	0	2	1	1	NA	NA	NA	NA	11/16
Lisee *et al*[39]	2	1	2	1	1	2	1	1	2	2	2	1	18/24
Toomy *et al*[40]	2	1	2	2	0	2	1	1	2	1	1	2	17/24
Triplett and Kuenze[41]	2	2	2	1	1	1	0	1	2	2	1	1	16/24

All items are scored 0 (not reported), 1 (reported but inadequate) and 2 (reported and adequate). The maximum score for non-comparative studies is 16 and the maximum score for comparative studies is 24. 1, a clearly stated aim; 2, inclusion of consecutive patients; 3, prospective collection of data; 4, endpoints appropriate to the aim of the study; 5, unbiased assessment of the study endpoint; 6, follow-up period appropriate to the aim of the study; 7, loss to follow-up less than 5%; 8, prospective calculation of the study size; 9, an adequate control group; 10, contemporary groups; 11, baseline equivalence of groups; 12, adequate statistical analyses.
NA, not applicable.

the guidelines of 10 000 daily steps should be interpreted with some caution.

CONCLUSION

The obtained results of this systematic review with meta-analysis unequivocally indicated that individuals who underwent ACLR spent significantly less time in MVPA per week, MVPA per day and steps per day relative to their non-injured counterparts. Additionally, although they participated in 316.8 min in weekly MVPA, the count of daily steps has been considerably below recommended values. Based on the highlighted facts, there is quite compelling evidence that ACLR negatively affected the objectively evaluated physical activity of the examined population. Overall, due to the strong inverse relationship between the level of physical activity and numerous health parameters, experts in the area of exercise science and medical workers need to try to create specific exercise programmes for this population to maintain or improve their health.

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