ΔΗΜΟΚΡΙΤΕΙΟ
ΠΑΝΕΠΙΣΤΗΜΙΟ
ΘΡΑΚΗΣ

Alterations of energy expenditure after ACL tear and reconstruction. A Systematic Review.

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ABSTRACT

Purpose: The ever-increasing sport level makes every single detail of the athlete's cardiorespiratory profile count and therefore, it's deemed crucial to clarify how the anterior cruciate ligament reconstruction (ACLR) affects the energy economy of an athlete compared to the ACL-deficient and healthy subjects. The purpose of this review was to systematically analyze the studies that have investigated the correlation between the energy-oxygen cost in patients following ACLR, in unreconstructed, and in intact ACLs.

Methods: This systematic review was conducted according to the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA). PubMed, Cochrane and Google Scholar databases were searched and 8 articles describing miscellaneous methods for the assessment of oxygen consumption in patients with ACL deficiency or ACL reconstructed knees were included.

Results: In total, 285 subjects were recorded with mean age of 29.61. The type of exercise that the patients were subjected to, varied among the studies, including one-leg cycling, exercise in closed kinetic chain and walking, jogging or running in various speeds and treadmill inclinations.

Conclusion: ACL insufficiency affects substantially the metabolic energy costs, resulting in increased energy expenditure. ACLR can help to partially reverse this condition, as significant improvements and a more efficient, energy-wise, locomotion is expected according to current literature.

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INTRODUCTION

Sports participation is increasing steadily, subsequently leading to more sports-related injuries [1]. In the United States, the incidence of anterior cruciate ligament (ACL) injuries exceeds 250,000 cases per year [2]. It is the commonest ligamentous injury, with football players being the most vulnerable group (53% of total tears), followed by the skiers and gymnasts who are at high risk too [3]. However, 20-25% of professional players are unfit to return to sport (RTS) after ACLR at the same level as before the injury, and young athletes who RTS have a 30% chance to sustain a secondary injury within 2 years [4]. ACL deficiencies can cause gait pattern alterations, and consequently the energy cost of walking changes as well. This is estimated by measuring the oxygen expenditure, which is higher in the injured limb compared to the healthy one [5].

The ever-increasing sport level makes every single detail of the athlete's cardiorespiratory profile count and therefore, it's deemed crucial to clarify how the anterior cruciate ligament reconstruction (ACLR) affects the energy economy of an athlete compared to the ACL-deficient and healthy subjects.

The purpose of this review was to systematically analyze the studies that have investigated the correlation between the energy-oxygen cost in patients following ACLR, in unreconstructed, and in intact ACLs.

METHODS AND MATERIALS

This systematic review was conducted according to the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA). It contains articles describing miscellaneous methods for the assessment of oxygen consumption in patients with ACL deficiency or ACL reconstructed knees.

Two authors did a thorough systematic search of the literature on the 24th of October 2022, including articles from three databases (PubMed, Cochrane and Google Scholar). The following search strategy was utilized to find any relevant articles: (ACL reconstruction OR ACL deficiency) AND (oxygen consumption OR energy expenditure OR energy cost OR walking economy OR VO2max). Any discrepancy between the authors with regards to selection of retrieved studies was resolved by a third author.

RESULTS

In this systematic review 8 studies were included. Out of them, 2 were Randomized clinical trials (RCTs) [12,16], 5 were prospective comparative studies [1-3,11,14] and 1 prospective cohort study [5]. In total, 285 subjects were participated, 235 males and 50 females, with mean age of 29.61, mean heigh of 1.76 m, mean body mass of 75.62 kg and mean BMI of 24.8. The mean time of injury since the ACLR was 5,33 months. The type of exercise that the patients were subjected to, varied among the studies, including one-leg cycling, exercise in closed kinetic chain and walking, jogging or running in various speeds and treadmill inclinations. The graft type in the group of ACLR was bone patellar tendon bone (BPTB) autograft in 53 patients, Hamstrings tendons in 43.

The energy expenditure of an ACL-deficient patient is considerably higher than a healthy subject, not only during walking but during jogging as well. This finding can be attributed to altered gait kinematics that are usually developed in ACL-deficient patients, and primarily to "quadriceps avoidance" pattern, meaning a sustained knee flexor moment during mid-stance. ACLR could improve the efficiency of walking by lowering the demands for energy. Moreover, the type of ACL graft (Hamstrings vs BPTB) and its role on metabolic energy cost is still uncertain, but to date both graft types are proven equal, without significant differences in respect of walking economy.

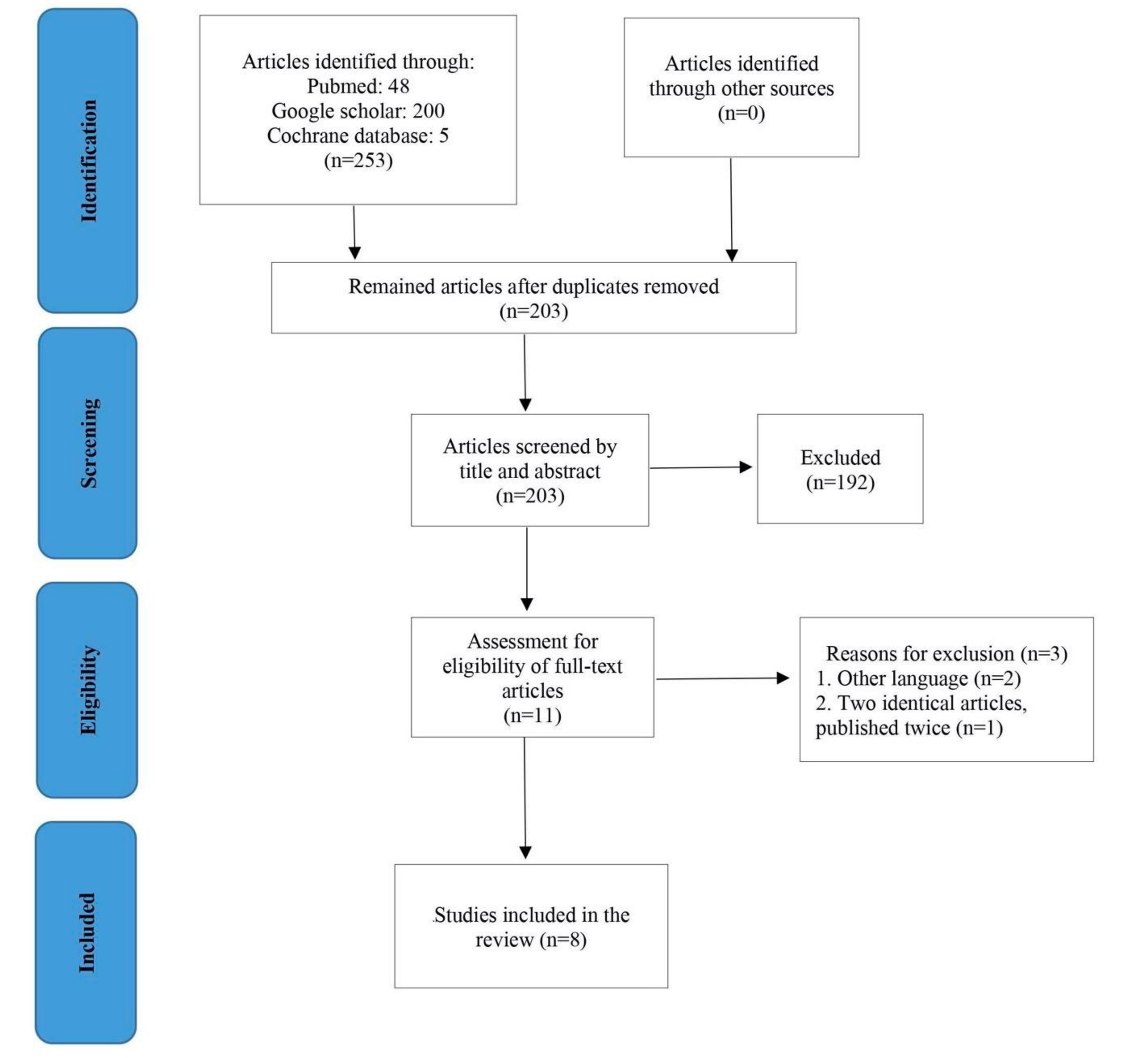

Figure 1. Flow chart.

DISCUSSION

The premise of this systematic review is that the metabolic cost and the energy consumption, in various sports activities, is higher in subjects with ACL deficiency, but is this also observed in athletes after ACLR? Undoubtedly, a native ACL constitutes a valuable knee stabilizer and energy sparer and as a result, the point of interest is focused, nowadays, on the energy consumption of an athlete with ACL deficiency or after ACLR. The ever-increasing sport level, especially in sports requiring frequent cutting maneuvers like football, makes every single detail of the athlete's cardiorespiratory profile count and therefore, it's deemed crucial to clarify how the ACLR affects the energy economy of an athlete compared to the ACL-deficient and healthy subjects.

	STUDY TYPE	LEVEL OF EVIDENCE	GROUPS	NUMBER	GENDER	AGE (Y) (mean ± sd)	HEIGHT (m) (mean ± sd)	BODY WEIGHT (kg) (mean ± sd)	BMI (kg/m2) (mean ± sd)	TIME OF INJURY (m) (mean ± sd)	TYPE OF EXERCISE	SPORT LEVEL	GRAFT TYPE
Olivier 2010 [16]	Randomized clinical trial	I	G1: RH without aerobic training G2: RH with aerobic training	G1: 12 G2: 12	24 M	G1: 23.31 ± 3.12 G2: 25.11 ± 3.41	G1: 1.81 ± 0.09 G2: 1.79 ± 0.08	G1: 78.12 ± 10.21 G2: 76.31 ± 8.21	N/A	2 ± 0.2	one-leg cycling with the untreated knee (OLC) A1: before RH program A2: after RH program	regional-level soccer players (4.7 ± 0.3 h/w)	21 BPTB 3 HT
Almeida 2018 [1]	Prospective comparative study	II	G1: before ACLR G2: 6 months after ACLR G3: control healthy group	G1,G2: 20 G3: 20	G1,G2: 20 M G3: 20 M	G1,G2: 21 (18-28) (median, range) G3: 20.5 (18-34)	G1,G2: 1.82 ± 0.08 G3: 1.79 ± 0.07	G1: 79.2 ± 10.1 G2: 79.3 ± 8.9 G3: 74.8 ± 6.2	G1: 23.7 ± 2.0 G2: 24.0 ± 2.0 G3: 23.4 ± 1.8	3 (1-12) (mean, range)	running to a treadmill	professional soccer player	20 HT
Andrade 2014 [2]	Prospective comparative study	II	G1: involved knee G2: uninvolved knee	18	18 M	33 ± 12	1.77 ± 0.05	79 ± 9	N/A	N/A	exercise in closed kinetic chain A1: moderate exercise A2: anaerobic threshhold A3: peak effort	physically active athletes (2.7 ± 0.7 h/w)	18 BPTB
Bagley 2020 [3]	Prospective comparative study	II	G1: leg with ACLR G2: the healthy leg of same subject	8	5 M 3 F	23 ± 3.5	1.697 ± 0.094	72.3 ± 17.3	N/A	N/A	single-leg cycling on both legs	6/8 competitive athletes	4 BPTB 2 HT 1 allograft
Colak 2011 [5]	Prospective cohort study	II	ACLR patients	8	8 M	31 (20-44) (mean, range)	1.73 (1.70-1.77) (mean, range)	76 (67-93) (mean, range)	25 (22-31) (mean, range)	27 (5-22) (mean, range)	G1: walking 50 m/min G2: walking 70 m/min G3: walking 90 m/min	N/A	8 HT
McHugh 1994 [14]	Prospective comparative study	II	G1: ACL deficiency G2: healthy control	G1: 30 G2: 98	G1: 21M, 9F G2: 60M, 38F	G1: 30.1 ± 1.1 G2: 33 ± 9.7	G2: 1.718 ± 0.012 G2: 1.719 ± 0.093	G1: 74.8 ± 1.8 G2: 69.6 ± 12.4	N/A	N/A	Walking and jogging A1: 53.6 m/min A2: 80.5 m/min A3: 107.2 m/min A4: 134.1 m/min A5: 160.9 m/min	N/A	-
Iliopoulos 2017 [11]	Prospective comparative study	II	G1: ACL rupture without ACLR G1a: copers G1b: non-copers G2: control group	G1: 19 G1a:10 G1b:9 G2: 10	G1: 19 M G2: 10 M	G1: 25.0 ± 5.6 G1a: 24.8 ± 6.1 G1b: 25.2 ± 5.3 G2: 25.6 ± 6.4	G1: 1.788 ± 0.077 G1a: 1.791 ± 0.0103 G1b: 1.785 ± 0.038 G2: 1.812 ± 0.0102	G1: 82.4 ± 19.6 G1a: 79.5 ± 21.0 G1b: 85.6 ± 18.6 G2: 89.7 ± 9.8	G1: 25.5 ± 4.7 G1a: 24.4 ± 3.9 G1b: 26.8 ± 5.4 G2: 25.3 ± 1.9	N/A	A1: flat treadmill A2: uphill treadmill A3: downhill treadmill	sport activities (3-6 t/w)	-
Iliopoulos 2017 [12]	Randomized clinical trial	I	G1: ACLR with BPTB G2: ACTR with HT G3: control group	G1: 10 G2: 10 G3: 10	G1: 10 M G2: 10 M G3: 10 M	G1: 24.8 ± 5.0 G2: 26.7 ± 7.2 G3: 26.5 ± 4.6	G1: 1.816 ± 0.038 G2: 1.752 ± 0.056 G3: 1.794 ± 0.083	G1: 88.7 ± 19.2 G2: 77.7 ± 19.0 G3: 81.9 ± 13.7	G1: 26.7 ± 5.6 G2: 24.6 ± 4.3 G3: 26.1 ± 2.2	N/A	A1: flat treadmill A2: uphill treadmill A3: downhill treadmill	sport activities (3-6 t/w)	10 HT 10BPTB

Table 1. Studies characteristics. Abbreviations: RH; rehabilitation, ACLR; anterior cruciate ligament reconstruction, ACL; anterior cruciate ligament, BPTB; bone patellar tendon bone, HT; hamstring tendons, M; males, F; females, N/A; not applicable, h/w; hours/ week, t/w; times/ week.

CONCLUSIONS

ACL insufficiency affects substantially the metabolic energy costs, resulting in increased energy expenditure during walking and exercise, but could also lead to poor cardiorespiratory fitness. ACLR can help reverse this condition, as significant improvements and a more efficient, energy-wise, locomotion is expected according to current literature. This is definitely an additional benefit to improved functional outcomes after ACLR and therefore, it should also be considered and brought up during consultation with patients that sustained an ACL tear. However, further high-quality research is warranted, in order to delineate, if ACLR is capable of bringing metabolic energy costs back to normal and also if graft types could have any impact on the outcome.

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