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PHYSIOLOGICAL PROFILE DIFFERENCES OF MALE AUSTRIAN LACROSSE ATHLETES: A COMPARISON TO US COLLEGIAN LACROSSE ATHLETES

RAZLIKE V FIZIOLOŠKEM PROFILU AVSTRIJSKIH IGRALCEV LACROSSA: PRIMERJAVA Z AMERIŠKIMI IGRALCI V UNIVERZITETNI LIGI LACROSSE

ABSTRACT

The sport of lacrosse has undergone rapid development over the past decade. However, little attention has been paid to the physiological requirements of lacrosse. Therefore, this paper aims to (1) describe the physiological profile of male lacrosse athletes and compare these findings with the findings of existing research and (2) examine the relationship between playing position, body composition and test performance.

Eighteen male Austrian national team lacrosse players participated (age: 23.1 ±4.0 years). All players performed a lacrosse-specific test battery to assess their body composition, flexibility, lower-body power, speed, agility, maximal strength, local muscular endurance, lacrosse skills, and aerobic capacity.

The results showed that compared to US college lacrosse players, Austrian players had significantly lower body fat (P=0.000, 10.5 ±2.0%), vertical jump (P=0.006, 52.0 ±5.5 cm), and one-repetition-maximum (1RM) back squat and bench press (P=0.015, 107.4 ±16.1 kg; P=0.000, 75.5 ±11.2 kg) values. Longer t-test (P=0.000, 10.32 ±0.51 s) and 1.6 km (P=0.000, 386.2 ±29.2 s) times and faster linear sprint (P=0.000, 5.30 ±0.14 s) times were also recorded for Austrian players. Additionally, significant correlations between body composition and performance results were reported for vertical jump height (r=-0.67, P=0.002), linear sprint (r=0.68, P=0.002), and 1.6 km times (r=0.59, P=0.010).

The results show that compared to their Austrian counterparts, male US college lacrosse players have higher overall fitness levels. Further, specific fitness tests results may help implement proper athletic training programmes to increase performance and reduce injuries in the sport of lacrosse.

Keywords: team sport, performance testing battery, body composition

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IZVLEČEK

Šport lacrosse se v zadnjem desetletju zelo hitro razvija. Vendar pa je se premalo pozornosti namenja fiziološkim zahtevam lacrossa. Zato je namen tega prispevka (1) opisati fiziološki profil moških športnikov v lacrossu in primerjati ugotovitve z rezultati opravljene raziskave ter (2) preučiti odnos med igralnim položajem, telesno zgradbo in uspešnostjo v testih.

Sodelovalo je 18 avstrijskih članov državne reprezentance lacrossa (starost: 23,1 ± 4,0 let). Vsi igralci so opravili nabor testov, specifičnih za lacrosse, s katerim smo ocenili njihovo telesno zgradbo, prožnost, moč spodnjega dela telesa, hitrost, agilnost, maksimalno moč, lokalno mišično vzdržljivost, spretnosti lacrosse in aerobno sposobnost.

Rezultati so pokazali, da so imeli avstrijski igralci, v primerjavi z ameriškimi igralci univerzitetne lige lacrosse, značilno nižje vrednosti telesne maščobe (P = 0,000, 10,5 ± 2,0 %), vertikalnega skoka (P = 0,006, 52,0 ± 5,5 cm) ter maksimalno vrednost pri eni ponovitvi (1RM) počepa z bremenom zadaj in dviga uteži leže na klopi (P = 0,015, 107,4 ± 16,1 kg; P = 0,000, 75,5 ± 11,2 kg). Tudi pri avstrijskih igralcih smo zabeležili daljši čas t-testa (P = 0,000, 10,32 ± 0,51 s) in teka na 1,6 km (P = 0,000, 386,2 ± 29,2 s) ter hitrejši linearni sprint (P = 0,000, 5,30 ± 0,14 s). Poleg tega so bile zabeležene značilne korelacije med zgradbo telesa in rezultati uspešnosti pri višini vertikalnega skoka (r = -0,67, P = 0,002), linearnega sprinta (r = 0,68, P = 0,002) in časa teka na 1,6 km (r = 0,59, P = 0,010).

Rezultati kažejo, da so ameriški igralci univerzitetne lige lacrosse v primerjavi s svojimi avstrijskimi vrstniki beležili višje vrednosti splošne telesne pripravljenosti. Poleg tega lahko specifični rezultati testov pomagajo pri izvedbi ustreznih programov športnih treningov, s čimer izboljšajo uspešnost igre in zmanjšajo tveganje za poškodbe v lacrossu.

Ključne besede: ekipni šport, nabor testov za merjenje uspešnosti, telesna zgradba

INTRODUCTION

Lacrosse, also known as "Baggataway", has its roots in Native American culture (Vennum, 1994). Today, the Federation of International Lacrosse consists of 55 members located all over the world (Federation-of-International-Lacrosse, 2017), with 29 of those members also participating in the European Lacrosse Federation (2016). Due to its North American roots, the biggest national governing body of men's and women's lacrosse is located in the United States of America. Increasing participation numbers are being recorded both in North America and other parts of the world. This trend continues with 19 nations participating in the 2013 Women's Lacrosse World Cup (Federation-of-International-Lacrosse, 2013) and 38 nations participating in the Men's Lacrosse World Championship in 2014 (Federation-of-International-Lacrosse, 2014).

Although lacrosse has a long history and growing participation numbers, knowledge of the physiological requirements of lacrosse is quite limited. Most recent research has focused on injury scenarios (Carter, Westerman, Lincoln, & Hunting, 2010; Caswell, Lincoln, Almquist, Dunn, & Hinton, 2012; Hinton, Lincoln, Almquist, Douoguih, & Sharma, 2005; Lincoln, Caswell, Almquist, Dunn, & Hinton, 2013). Nevertheless, a few studies have examined the physiological profile and indicators of performance in the sport of lacrosse.

Collins et al. (2014) examined the physiological profiles and the relationship between body composition and performance in Division III men's lacrosse. They tested fifty-four intercollegiate athletes and found that body fat percentage (%BF) positively correlates with 300 yard shuttle time (first attempt: r=0.64, P=0.00; second attempt: r=0.68, P=0.00), total 300 yard shuttle time (r=0.69, P=0.00) and 1 mile run (r=0.44, P=0.00) values. Another study by Hoffman et al. (2009) investigated performance differences between starters and non-starters in NCAA Division III female lacrosse athletes during the preseason period. Subjects were tested on their one-repetition-maximum (1RM) for bench press, back squat, vertical jump height, aerobic and anaerobic capacity, 40 yard sprint, and agility run performance. Additional anthropometric analyses were executed. Significant (P<0.05) results revealed that attackers were 15.7% heavier than midfielders and that defenders showed greater back squat values (10.3%) than midfielders. Attackers were more powerful in the Wingate anaerobic power test (peak and mean power) than both defenders (by 19.6% and 13.4%, respectively) and midfielders (by 21.2% and 13.4%, respectively). No significant differences were found among the groups in any speed and agility measure.

Gutowski and Rosene (2011) designed a preseason testing battery for male lacrosse athletes to assess sport-specific requirements. In their study, they described the test protocols and gave standard value recommendations for all tests in Division III male lacrosse players. Steinhagen et al. (1998) observed 30 male college club-sport lacrosse athletes to quantify the physiological response to standard testing procedures. Athletes showed similar blood chemistry and lipid profiles to those in rodeo and field hockey. They had higher %BF than college athletes in other sports and similar overall mean lean body mass to those reported for professional soccer players. The aerobic capacity of lacrosse athletes was comparable to other intermittent-activity sports such as basketball, football and rodeo, while their anaerobic capacity seemed to be higher than that for rugby and soccer players but lower than that for Olympic ice hockey players. Another study by Enemark-Miller et al. (2009) described the physiological profile of NCAA Division I women's lacrosse athletes. Fitness tests selected from standard physical fitness assessments were conducted. The tests included endurance (Bruce Protocol VO_{2max} test and 1 mile run), flexibility (sit-and-reach test), muscular endurance (push-up, sit-up and 60% of 1RM for squat), muscular strength (1RM for bench press and squat), body composition (air displacement plethysmograph), muscle torque (quadriceps maximal voluntary isometric contraction), grip strength (hand dynamometer), vertical jump height, and 100 and 200 yard sprints. The results showed a similar physiological profile to basketball, soccer and track athletes with average flexibility values and higher % BF.

Performance tests can be a good predictor of on-field performance. However, much uncertainty remains about the structure of and tests used in a test battery. To date, only few studies exist which have investigated the physiological profile of lacrosse athletes by using a complex performance testing battery. To the best of our knowledge, resent research is limited to US athletes and no study with the focus on European lacrosse players exists. Therefore, this study aims to describe the physiological profile of male Austrian national team lacrosse athletes and to compare their profile with existing research of US intercollegiate lacrosse athletes. Additionally, the current Austrian study presents theses profile data with respect to the playing position, which up to now has been done only once in a study by Steinhagen et al. (1998). We hypothesized that the fitness level of male Austrian national team lacrosse athletes is lower than in US college lacrosse athletes, and the physiological profile to be influenced by playing position. Furthermore, test results provide information about the relationship between body fat and performance.

MATERIALS AND METHODS

Experimental Approach to the Problem

All tests were selected based on standard physical fitness assessments and conducted over a two-day session. On the first day, tests included, in order, a 15-minute dynamic upper and lower body warm-up and stretching routine, anthropometric measurements, sit and reach, countermovement jump, 36.6 m sprint, 1RM back squat, 1RM bench press, 60% of the 1RM back squat to fatigue, curl-up, push-up, and a 1.6 km run. The second day consisted of a 15-minute dynamic upper and lower body warm-up and stretching routine, t-test, pro-agility test, and a wall-ball test. All testing procedures occurred at the Centre for Sport Science and University Sports in Vienna, supervised by the research team using a standardized protocol.

Participants

Eighteen male members (4 attackers, 9 midfielders, and 5 defenders) of the Austrian lacrosse national team participated in the study (age: 23.1 ±4.0 years; body mass: 80.7 ±9.5 kg; stature: 180.8 ±0.7 cm). The study was conducted in accordance with the Declaration of Helsinki. All subjects provided informed consent after reading a description of all aspects of the physical testing and the anonymization of the data that had been approved by the University of Vienna Ethics Review Board (Reference Number: 00190). Participants were asked to refrain from exercising for 12 hours and to follow their normal dietary guidelines before testing.

Procedure

The designed test battery included the listed tests, in the order presented, to create the athlete's physiological profile.

Anthropometric Measurements

Measurements were assessed using the measurement of skinfolds following the International Society for the Advancement of Kinanthropometry (ISAK) guidelines. According to the standardized procedures of the ISAK manual, subjects were measured for stretch stature (cm) using a stadiometer (Seca, Hamburg, Germany) and body mass (kg) using a calibrated scale (Seca, Hamburg, Germany). An 8-site skinfold technique using a Harpenden calliper (Baty International, West Sussex, England) was conducted. The girths of the arm when relaxed, flexed and tensed, waist, gluteus, and calf were measured using a metal tape. In the final step, humerus and femur breadth were measured using a calliper (Baty International, West Sussex, England). With an Excel protocol, body fat percentage and body mass index were calculated according to ISAK equations. Skinfold measurement has been described as reliable and valid to assess body composition (Hume & Marfell-Jones, 2008; Perini, Oliveira, Ornellas, & Oliveira, 2005).

Sit and Reach

To evaluate participants' flexibility, a sit and reach box was used. The test has proven to be a reliable and valid flexibility assessment test (Baltaci, Un, Tunay, Besler, & Gerçeker, 2003; Hui & Yuen, 2000; Miller, 2012). According to the American College of Sports Medicine (ACSM) guidelines (Thompson, 2010), the subject sat barefooted with full knee extension and heels placed against the box. Then, the participant slowly bent forward, with both hands parallel, pushing the measuring portion as far as possible, holding this position for approximately 2 s. The furthest distance reached with the fingertips for the best attempt of two trials was recorded to full centimetres. The toe location was set as the zero point.

Vertical Jump

Participants maximum jump height was assessed by a Vertec jump testing device (Sports Imports, Hilliard, Ohio) following the standard procedure (Haff & Triplett, 2016). The test has been described as reliable and valid to assess jump height (Rodríguez-Rosell, Mora-Custodio, Franco-Márquez, Yáñez-García, & González-Badillo, 2017). Standing touch height was measured flat-footed reaching the highest vane possible with the dominant hand. Located directly underneath the Vertec with no stutter step allowed, athletes performed a counter movement. Participants were instructed to flex the knees and hips while swinging the arms backward and tap the highest vane possible with the dominant arm during the jump. The best of three trials was recorded to the nearest 0.5 inches. All assessed maximum jump heights were then transformed into centimetres.

Linear Speed

Speed was determined by a 36.6 m straight-line sprint test on an indoor track. Time was assessed using electronic laser time gates (Microgate, Bolzano, Italy). The best attempt of two trials was recorded to the nearest 0.01 s. The 36.6 m straight-line sprint test has been described as reliable and valid (Jay R. Hoffman, 2006; Mann, Ivey, Brechue, & Mayhew, 2015; Miller, 2012).

Maximum Muscular Strength

Maximum muscular strength was evaluated on adjustable squat stands (Casall, Stockholm, Sweden) with a barbell (Eleiko, Halmstad, Sweden), weight plates and two safety locks. For bench press, a standardized bench (Casall, Stockholm, Sweden) was used. To evaluate the 1RM, the tester followed the standard procedure for back squat and bench press (Haff & Triplett, 2016). For all trials, two spotters helped on a failed attempt. First, athletes performed a warm-up of 5 to 10 repetitions with a light to moderate weight. Before the first 1RM attempt, two sets of 2 to 5 repetitions were completed. For the 1RM, the load was increased or decreased until athletes completed one repetition with proper exercise technique. To ensure adequate recovery, a 2- to 4-minute rest period was given between attempts. Participants first performed 1RM for back squat followed by 1RM for bench press. The tester recorded the maximum load used for one repetition with proper exercise technique. 1RM tests have been proven to be reliable and valid to measure maximal strength (Jay R. Hoffman, 2006; McMaster, Gill, Cronin, & McGuigan, 2014; Miller, 2012).

Local Muscular Endurance

After a 10-minute rest period from the maximum muscular strength tests, athletes performed a local muscular endurance back squat test. The back squats were performed until failure at 60% of the evaluated 1RM back squat weight. The tester registered the number of repetitions with proper exercise technique. The authors did not find any published reliability and validity data for the back squat to failure test. Muscular endurance of the abdominal muscles was assessed by the partial curl-up test as standardized in National Strength and Conditioning Association (NSCA) Essentials of Strength and Conditioning (Haff & Triplett, 2016). Participants lay on a mat with knees bent at a 90° angle and arms at the sides resting on the floor. The fingertips touched a 10 cm piece of tape. Another piece of tape was located parallel to the first one 12 cm further down the mat. During the test, a metronome was set to 40 beats per minute. Athletes were instructed to perform 20 controlled curl-ups per minute, in time with the metronome. A valid curl-up was considered if the individual lifted the shoulder blades off the mat until fingertips touched the second piece of tape followed by moving back into the starting position with the upper back touching the floor before the next repetition. The tester recorded the number of valid curl-ups without pausing to a maximum of 75 repetitions. According to Miller (2012), no data exist to prove reliability and validity for the partial curl-up test. For muscular endurance of the upper body, a push-up test according to ACSM's Guidelines for Exercise Testing and Prescription (Thompson, 2010) was used. This test has been proven to be reliable and valid (Miller, 2012). Participants started in a standard push-up starting position, lowering their body until the chest made contact with the tester's fist held vertical against the ground. The number of continuously done repetitions until failure was recorded.

Aerobic Capacity

After a 20-minute break, athletes performed a 1.6 km run on an outdoor 400 m track. Subjects were divided in two groups. Each researcher assessed the time of two to three athletes using a stopwatch to the nearest second. The 1.6 km run has been described as reliable and valid to measure aerobic capacity (Miller, 2012).

Agility

On the next day, athletes performed a t-test and a pro-agility test following standard procedures (Haff & Triplett, 2016). All agility assessment tests were performed in a gym. They have been described as reliable and valid to assess the speed of changes in direction (Miller, 2012; Sporis, Jukic, Milanovic, & Vucetic, 2010; Stewart, Turner, & Miller, 2014). For the t-test, four cones were placed (Figure 1). Subjects started in a standing position at cone A. On the tester's verbal signal, the athletes sprinted to cone B, touching the base of the cone with the right hand. Second, while facing forward and not crossing the feet, the athlete shuffled to point C, touching the base of the cone with the left hand. Third, subjects shuffled to the right side to point D, touching the cone with the right hand. Then, they shuffled to the left and touched cone B with the left hand. Finally, athletes ran backward past point A, at which time the watch was stopped. After a short break, each athlete performed a second trial in the other direction, shuffling to the right side first. The best time of two trials was recorded to the nearest 0.1 s using a stopwatch. For the pro-agility test, three parallel lines 4.6 m apart were marked on the floor (Figure 2). Athletes started at the middle line in a three-point stance. On a verbal signal, the athletes sprinted to the line on the left, changed direction, sprinting to the line on the right, and after changing direction again, sprinting back to the centre line. Before each change of direction, subjects had to touch all indicated lines with one foot. The best time of two trials, in one direction or the other, was recorded to the nearest 0.01 s using laser time gates (Microgate, Bolzano, Italy).

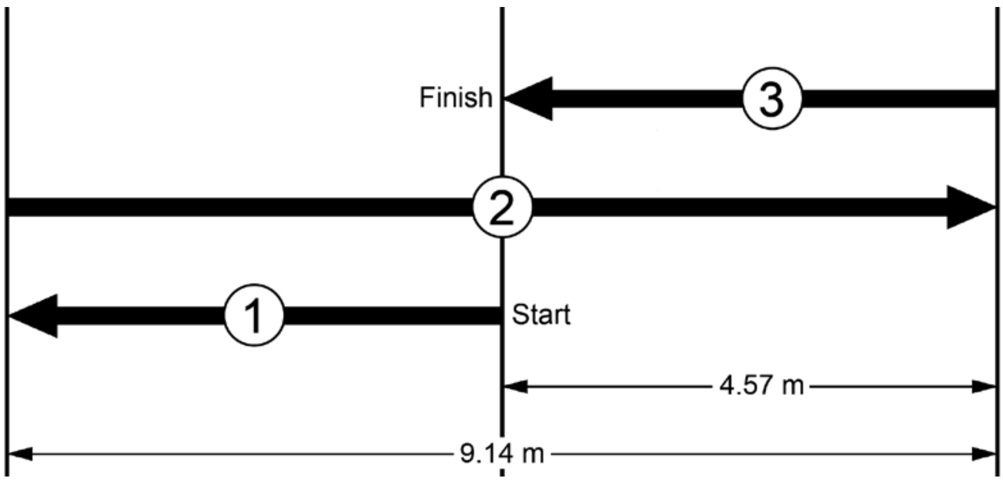

Figure 1. Floor layout for the t-test (based on NSCA, 2016, p.280). Note: The above diagram shows the protocol in one direction. Athletes performed the test in both directions.

Figure 2. Floor layout for the pro-agility test (based on NSCA, 2016, p.282). Note: The above diagram shows the protocol in one direction. Athletes performed the test in both directions.

Lacrosse Skills

To assess participants passing and catching abilities, a lacrosse-specific wall-ball test was implemented. Subjects stood 2.0 m behind a line in front of a wall, facing a 50x50 cm square. The line and square were marked with tape. The lower edge of the square was located at a height of 2.3 m (Figure 3). On the tester's verbal signal, subjects threw a lacrosse ball in the square against the wall and caught it again using their stick. This procedure was repeated for 30 s. The test ended if the ball dropped on the ground or the 30 s period expired. The tester recorded the direct hits in or on the marks of the square of two trials. The mean values of the proper repetitions of both trials were calculated. Thus far, no data exist to prove the reliability and validity of this test.

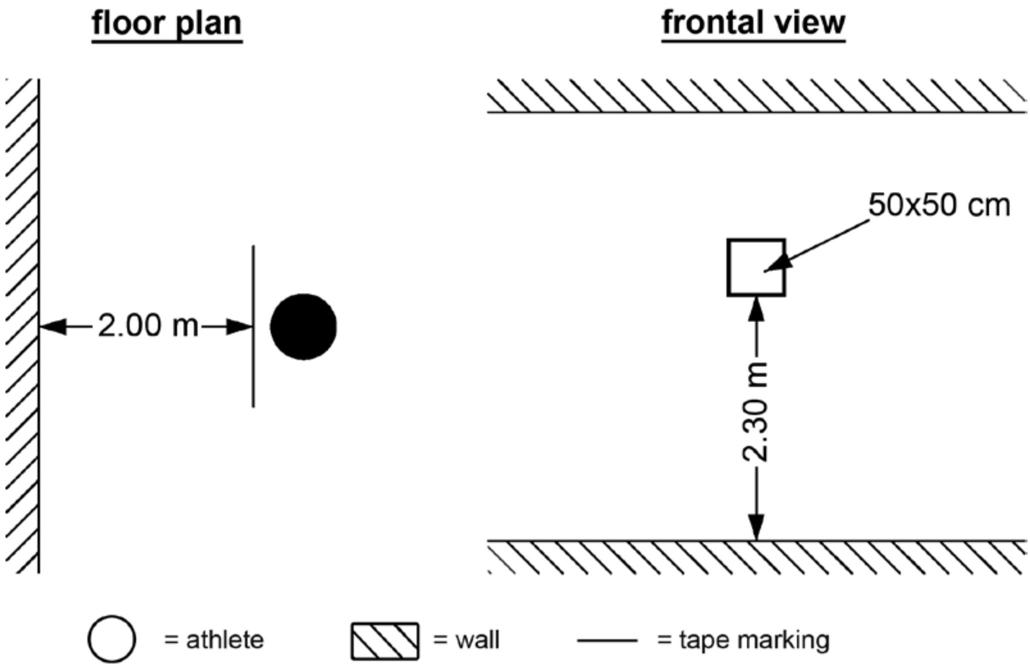

Figure 3. Lacrosse passing and catching wall-ball test protocol.

Statistical Analyses

For statistical analysis, IBM software SPSS Version 22 and Microsoft Excel 2010 were used. The mean and standard deviation (SD) were calculated for all characteristics and tested values. Statistical comparisons between the collected data and previously published US college athlete data (Collins et al., 2014; Gutowski & Rosene, 2011; Steinhagen et al., 1998) were executed by a 1-sample t-test. Additionally, a one way ANOVA was used to determine playing position differences in test performances. Data assumption of normality was verified using the Shapiro-Wilk test and histograms. To determine the magnitude and direction of the possible relationship between %BF and fitness test parameters, bivariate Pearson correlation coefficients *(r)* were calculated. The magnitude of the correlations was determined as trivial (0-0.19), small (0.20-0.49), medium (0.50-0.79) and large (≥0.80) (Cohen, 1992). The significance level for all tests was set at $P<0.05$. All calculations are based on a 95% confidence interval.

RESULTS

The mean values and standard deviation for performance test results are presented in Table 1. Compared with published work for male college lacrosse athletes (Collins et al., 2014; Steinhagen et al., 1998), male Austrian national team lacrosse players showed no significant difference in height and weight. Based on the data shown in Table 1, Austrian athletes had significantly lower values for vertical jump ($P=0.006$, 52.0 ±5.5 cm), 1RM bench press ($P=0.000$, 75.5 ±11.2 kg), and 1RM back squat ($P=0.015$, 107.4 ±16.1 kg) compared with Division III male college lacrosse athletes (Gutowski & Rosene, 2011). In addition, the trial time for the t-test (P=0.000, 10.32 ±0.51 s) was longer in the Austrian athletes than that in the Division III athletes. However, the Austrian athletes covered a significantly shorter 36.6 m sprint distance (P=0.000, 5.30 ±0.14 s). Likewise, Collins et al. (2014) reported a significant lower 1.6 km time (P=0.000, 386.2 ±29.2 m) and a higher %BF (P=0.000, 10.5 ±2.0%) value for Division III lacrosse athletes than that recorded in the present study. Accordingly, recorded %BF values were significantly lower (P=0.005 and P=0.000, respectively) than those reported by Gutowski & Rosene (2011) and Steinhagen et al. (1998). Data for the lower-body local muscular endurance showed significantly more repetitions (P=0.000, 28.3 ±6.0) in male Austrian lacrosse players than for Division I women's lacrosse athletes, published by Enemark-Miller et al. (2009).

In consideration of playing position, defenders were significant taller than midfielders (P=0.006, defenders: 188.4 ±4.7 cm; midfielders: 177.3 ±6.4 cm). It was also noted that defenders were heavier (defenders: 91.1 ±6.8 kg; midfielders: P=0.010, 77.0 ±7.1 kg; attackers: P=0.022, 76.1 ±8.3 kg) than players at other positions. All other physiological profile parameter were similar between playing positions.

Table 2 shows the correlations between body composition and fitness test performance results. A significant, negative correlation was reported for vertical jump height (r=-0.67, P=0.002). The data on %BF and linear sprint (r=0.69, P=0.002), and 1.6 km time (r=0.59, P=0.010) showed a significant, positive correlation. A nonsignificant positive small correlation was reported between increased %BF and the t-test (r=0.47, P=0.051), and pro-agility test (r=0.40, P=0.103) values.

DISCUSSION AND CONCLUSIONS

The aim of the present study was to describe and compare the physiological profile of male Austrian national team lacrosse players with those previously reported in male US college lacrosse athletes (Collins et al., 2014; Gutowski & Rosene, 2011; Steinhagen et al., 1998). The current results show significantly lower values for lower-body explosive power and overall strength in Austrian athletes than those in Division III athletes. Similarly, Austrian lacrosse players also performed worse in agility tests, including change of direction. These findings are supported by significant higher pro-agility trial times (P=0.00, 4.77 ±0.20 s) compared with male Division I football players (2016). The differences in agility performance may result from the significantly reduced power and strength. However, this hypothesis is not supported by significantly better linear sprint results in Austrian athletes. According to findings by Steinhagen et al. (1998) Austrian defender are taller than midfielders (P=0.006, 188.4 ±4.7 cm) and heavier than midfielders and attackers (P=0.010; P=0.022, 91.1 ±6.8 kg). In contrast, male Austrian national team lacrosse players do not show significant differences in any other physiological profile parameters, regarding their playing position. Further, in contrast to recent findings by Collins et al. (2014), who suggested an increased %BF as a negative predictor in aerobic performance, Austrian subjects showed significantly lower %BF values (P=0.000, 10.5 ±2.0%) than those of Division III athletes. Moreover, significantly lower aerobic capacity (P=0.000, 386.2 ±29.2 s) values were recorded for Austrian lacrosse players.

To the best of the authors' knowledge, no data have been published for male lacrosse athletes regarding curl-up, push-up and pro-agility tests. Therefore, the mean scores recorded in the present study were compared with normative reference data from sport-relevant guidelines

Table 1. Mean ± SD anthropometric and athletic performance comparison between Austrian male national team lacrosse players and current literature.

Physical performances	Present Study	Gutowski & Rosene	Steinhagen et al.	Collins et al.	NSCA	ACSM	CSEP	Enemark-Miller et al.	P-value
Age (years)	23.1±4.0	N/A	21.9±0.5	19.6±1.2	N/A	N/A	N/A	N/A	N/A
Height (cm)	180.8±0.7	N/A	182.5±1.8	178.5±1.2	N/A	N/A	N/A	N/A	0.196/0.294
Body Mass (kg)	80.7±9.5	N/A	81.7±2.0	81.7±15.0	N/A	N/A	N/A	N/A	0.666/0.666
Sit and Reach (cm)	13.7±5.3	N/A							
Vertical Jump (cm)	52.0±5.5	56.0	N/A	N/A	N/A	N/A	N/A	N/A	0.006**
1RM Bench Press (kg)	75.5±11.2	88.5	N/A	N/A	N/A	N/A	N/A	N/A	0.000**
1RM Back Squat (kg)	107.4±16.1	118.0	N/A	N/A	N/A	N/A	N/A	N/A	0.015*
60% Back Squat (kg)	28.3±6.0	N/A	N/A	N/A	N/A	N/A	N/A	20.3±9.7	0.000**
Partial Curl-up (rep)	56.3±17.0	N/A	N/A	N/A	N/A	above average	N/A	N/A	N/A
Push-up (rep)	36.6±9.0	N/A	N/A	N/A	N/A	N/A	excellent	N/A	N/A
36.6 m Sprint (s)	5.30±0.14	5.50	N/A	N/A	N/A	N/A	N/A	N/A	0.000**
T-test (s)	10.32±0.51	9.50	N/A	N/A	N/A	N/A	N/A	N/A	0.000**
Pro-agility Test (s)	4.77±0.20	N/A	N/A	N/A	4.54±0.27	N/A	N/A	N/A	0.000**
Wall-ball Test (rep)	27.3±7.8	N/A							
1.6 km Run (s)	386.2±29.2	N/A	N/A	348.8±20.7	N/A	N/A	N/A	N/A	0.000**
Body Fat (%)	10.5±2.0	12.0	13.5±1.1	13.3±5.7	N/A	N/A	N/A	N/A	0.005**/0.000**/0.000**

Significant difference between the present study and the current literature: *P<0.05, **P<0.01

Table 2: Correlation between body fat (%) and performance test.

	% BF Skinfold	Sit and Reach	Vertical Jump	1RM Bench Press	1RM Back Squat	60% Back Squat	Partial Curl-up	Push-up	36.6 m Sprint	T-test	Pro-agility Test	Wall-ball Test	1.6 km Run
% BF Skinfold	1	-0.02	-0.67**	0.14	-0.05	-0.25	-0.02	0.01	0.69**	0.47	0.40	0.12	0.59*
Sit and Reach		1	0.31	0.44	0.12	-0.05	0.44	0.37	-0.20	-0.48*	-0.48*	0.62**	-0.27
Vertical Jump			1	0.23	0.08	0.30	0.34	-0.07	-0.79**	-0.58*	-0.47*	0.60	-0.51*
1RM Bench Press				1	0.69**	0.17	0.32	0.46	0.09	-0.15	0.01	0.45	0.09
1RM Back Squat					1	0.19	-0.03	0.33	0.05	-0.09	-0.06	0.37	-0.06
60% Back Squat						1	0.55*	0.50	-0.48	-0.09	-0.12	0.14	-0.41
Partial Curl-up							1	0.63*	-0.23	-0.25	-0.25	0.15	-0.34
Push-up								1	0.03	-0.28	-0.17	0.32	-0.31
36.6 m Sprint									1	0.64**	0.70**	-0.22	0.56*
T-test										1	0.77**	-0.33	0.66**
Pro-agility Test											1	-0.56*	0.59*
Wall-ball Test												1	-0.10
1.6 km Run													1

Significant correlation: *P<0.05, **P<0.01

(Haff & Triplett, 2016; Thompson, 2010). The partial curl-up mean score (56.3 ±17.0 repetitions) was above the 80th percentile of the ACSM's normative data (Thompson, 2010). Additionally, the push-up results (36.6 ±9.0 repetitions) placed the Austrian athletes within the "excellent" category, as defined by the Canadian Society for Exercise Physiology (Haff & Triplett, 2016). Compared with findings by Enemark-Miller et al. (2009), the findings of this study show that male Austrian national team players completed significantly more repetitions (P=0.000, 28.3 ±6.0 repetitions) in the 60% back squat test than those completed by female Division I lacrosse athletes. However, there are limitations as to how far these findings can be taken for comparison, as this test is lacking validation and reliability so far. Therefore, more research is required to collect and evaluate additional data. A reference data collection for the developed wall-ball test would be equally important. As this is the first study to use such a test to quantify lacrosse-specific passing and catching abilities, future studies should reclassify the collected data from the present study (27.3 ±7.8 repetitions) for male Austrian national team lacrosse athletes.

With a mixture of speed endurance and power production against external loads, muscular endurance seems to play an important role in the sport of lacrosse. Recent research has suggested that muscular endurance and on-field performance can be affected by body composition (Collins et al., 2014). According to previous studies (Collins et al., 2014; Potteiger, Smith, Maier, & Foster, 2010), increased %BF seems to have significantly negative effects on power, speed, and endurance parameters. Austrian athletes with higher %BF showed lower jump height scores and increased 1.6 km and 36.6 m times. These findings support the hypothesis that higher %BF is linked to an increased rate of fatigue, which may limit on-field performance. Further, a significant, medium correlation was recorded between %BF and jump performance, speed, and aerobic capacity. Similarly, a strong relationship was identified between jump performance, speed, agility values, and 1.6 km trial time (Table 2). These findings indicate that %BF is linked to several performance parameters and might be an indicator of the fitness level of lacrosse athletes.

The results of this study show some evidence that the physiological profile of male Austrian lacrosse players differs from that of US college lacrosse athletes. Austrian lacrosse athletes performed worse than their US counterparts in power, strength, agility, and endurance tests. However, Austrian lacrosse athletes showed lower %BF and better linear sprint values. In general, US college lacrosse athletes appear to have a higher fitness level than Austrian athletes. One reason for that could be a different playing and training level in the sport of lacrosse between the US and Europe. However, the present findings indicate possible areas of improvement in lacrosse-specific fitness programmes. Therefore, such programmes should consist of power and strength blocks to improve explosiveness and speed performance. Further, lacrosse specific agility and high-intensity endurance drills, with and without stick and ball, should be included for a better on-field performance transfer. In this context, future research should focus on the design of training and test regimes to improve and evaluate lacrosse-specific fitness programmes. The authors suggest to modify already verified tests from other field sports, such as the "Copenhagen Soccer Test" (CST) (Bendiksen et al., 2012), for the sport of lacrosse. This would enable coaches and trainers to use present and future data to design lacrosse-specific strength and conditioning programmes to improve on-field performance. With regard to technical parameters it is still unclear if SSG show higher numbers of ball touches and a positive transfer to match-play. Therefore, future studies should examine the game structure of the sport of lacrosse and compare results with SSG regimes. Additionally, this study indicates that %BF is a predictor of several performance indicators, especially power, speed, and endurance. These findings suggest that training programmes should focus on improving %BF and fat-free mass profiles of lacrosse athletes because body size can be a limiting performance factor.

In a lacrosse game, athletes are exposed to intermittent high-intensity activity, collisions, and rapid changes in direction (Polley, Cormack, Gabbett, & Polglaze, 2015). Therefore, the results of test batteries, such as those used in this study, can be used to monitor fitness as well as the effectiveness of conditioning programmes to prepare athletes for the physical demands of the sport of lacrosse. Thus, future research should design and verify lacrosse-specific test batteries and identify standard values for lacrosse athletes.

What does this article add?

The majority of lacrosse specific studies focus on injury scenarios. Hence, knowledge of the physiological requirements of lacrosse is quite limited. Our results provide novel insights into the physiological profile of elite male Austrian lacrosse players and show the differences to US collegian lacrosse athletes. Furthermore, our findings suggest that male Austrian lacrosse players have a lower overall fitness level compared to US lacrosse athletes. Based on results of the current study, it seems that especially anthropometric requirements differ between playing positions. Specifically, results do indicate possible areas of improvement in lacrosse-specific fitness programmes with a focus on power, strength, agility, and endurance performance. In addition, findings of this study suggest that training programmes should focus on improving %BF and fat-free mass profiles of lacrosse athletes. These parameters might be an indicator of the fitness level of athletes and can be used to increase performance and reduce injuries in the sport of lacrosse. Therefore, verified lacrosse-specific test batteries with standard values for male and female lacrosse athletes should support lacrosse coaches. These test batteries results can be used to monitor fitness levels of their athletes and effectiveness of conditioning programmes.

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