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Isokinetic Performance of Knee Flexor and Extensor Muscles in American Football Players from Brazil

Desempenho Isocinético de Flexores e Extensores de Joelho em Jogadores de Futebol Americano do Brasil

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Abstract - The isokinetic performance of thigh muscles has been related to athletic performance and risk for non-contact injuries, such as anterior cruciate ligament ruptures and hamstring strains. Although isokinetic profile of American football players from United States (USA) is widely described, there is a lack of studies comprising players acting outside the USA. The primary objective of this study was to describe the isokinetic performance of thigh muscles in elite American football players in Brazil. Secondarily, we aimed to compare the playing positions and compare the Brazilian players with high-level athletes from USA. Knee extensor (KE) and flexor (KF) muscles of 72 Brazilian players were assessed through isokinetic tests at 60°·s^{-1}. KE concentric peak torque was 276±56 N·m, while KF had concentric and eccentric peak torques of 151±37 N·m and 220±40 N·m, respectively. Offensive linemen players presented greater peak torque values than defensive lineman, halfbacks, and wide receivers (all comparisons are provided in the article). Brazilian players had lower scores than USA athletes for KE and KF peak torque values. In addition, a conventional torque ratio (concentric/concentric) lower than 0.6 was found in 76-83% of athletes, and a functional ratio (eccentric/eccentric) below to 1.0 in 94%. Bilateral asymmetry greater than 10% was verified in 26% and 43% of athletes for KE and KF muscles, respectively. Elite players in Brazil present high incidence of strength imbalance in thigh muscles, and they are below USA players in relation to torque production capacity of KE and KF muscles.

Key words: Football; Hamstring; Quadriceps; Sports; Torque.

Resumo – *O desempenho isocinético dos músculos da coxa são associados com o desempenho atlético e com o risco de lesões sem contato físico. Apesar do perfil isocinético dos jogadores de futebol americano que atuam nos Estados Unidos (EUA) ser amplamente pesquisado, poucos são os estudos com atletas fora dos EUA. O objetivo primário desse estudo era descrever o desempenho isocinético dos atletas de futebol americano no Brasil. Além disso, buscamos comparar as posições de jogo e comparar os de elite brasileiros e americanos. Os músculos extensores (EXT) e flexores (FLE) de joelho de 72 jogadores brasileiros foram avaliados por testes isocinéticos a 60°·s^{-1}. O pico de torque concêntrico de EXT foi de 276±56 N·m, enquanto os FLE tiveram pico de torque concêntrico e excêntrico de 151±37 N·m e 220±40 N·m, respectivamente. Jogadores de linha ofensiva apresentaram os maiores picos de torque (todas as comparações constam no artigo). Os jogadores brasileiros apresentaram valores inferiores aos atletas dos EUA para o pico de torque de EXT e FLE. Além disso, uma razão convencional (concêntrico/concêntrico) menor que 0,6 foi observada em 76-83% dos atletas, e uma razão funcional (excêntrico/concêntrico) abaixo de 1,0 foi encontrada em 94% dos atletas. Assimetrias bilaterais superiores a 10% foram verificadas em 26% e 43% dos atletas para EXT e FLE, respectivamente. Os jogadores de elite no Brasil apresentam alta incidência de desequilíbrios de força nos músculos da coxa e estão abaixo dos jogadores norte-americanos em relação à capacidade de produção de torque de EXT e FLE de joelho.*

Palavras-chave: *Esportes; Futebol americano; Isquiotibiais; Quadríceps; Torque.*

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INTRODUCTION

American football (AF), referred to as "football" by North Americans, is a team sport evolved in United States (USA) at late nineteenth century[1]. The game is played by 11 players each team, and playing positions are grouped in defensive positions (defensive backs, DB; linebackers, LB; defensive linemen, DL), offensive positions (quarterbacks, QB; offensive linemen, OL; wide receivers, WR; halfbacks, HB) and special positions (kickers, K; punters, P)[2]. Each playing position has specific demands during the game, thus successful players present specific characteristics in relation to body size and physical conditioning[3]. For instance, strength and power are imperative for line players (OL and DL) to perform tasks like charging, blocking and tackling; while speed, agility and maneuverability are the main characteristics for WR and DB[4].

National Football League (NFL) is the main AF league in the world. Every year, selection of new players comprises the NFL scouting combine, a weak-long event where collegiate football players perform physical and mental tests in front of NFL coaches, general managers, and scouts. Athlete's performance during the combine can affect their draft status and salary, and ultimately their career. Since lower limb strength is a highly-prized quality in AF players, isokinetic dynamometry is part of the NFL scouting combine. Zvijac et al.[5] published a retrospective study with isokinetic data collected in 1,252 college players during NFL scouting combines. These normative isokinetic data for AF players may be used to assess the conditioning status and the risk for future injuries[5].

Due to the game characteristics, contact with players is the primary injury mechanism in AF, and 47-57% of injuries affect the lower limbs[6,7]. Non-contact injuries represent 14% and 30% of injuries in competition and regular practice, respectively[6]. Among typical non-contact injuries, anterior cruciate ligament (ACL) ruptures (1.00 injury/1000 athlete-exposures)[6] and hamstring strains (1.67 injury/1000 athlete-exposures)[8] have been associated with some athletes' intrinsic features, such as the muscle strength imbalance between hamstring and quadriceps muscles (e.g., hamstring-to-quadriceps ratio)[9,10] and strength imbalance between preferred and non-preferred limbs (e.g., bilateral asymmetry)[10]. Thus, AF teams from USA have increasingly invested in isokinetic dynamometry tests[3].

Although AF popularity is growing and reaching fans in more than a hundred countries[2], studies outside the USA are scarce. As far as we know, there are only two studies about the incidence of injuries in Japanese[11] and Finish[12] athletes, and two studies about physical and performance characteristics of Japanese[13] and Brazilian[14] players. However, there is a lack of studies on the isokinetic performance of thigh muscles in AF athletes who play outside the USA. Therefore, the primary aim of this study was to describe isokinetic profile of knee extensor and flexor muscles in athletes who play in the elite level of AF in Brazil. In addition, we aimed to compare the playing positions and compare the Brazilian players with high-level athletes from USA.

METHODOLOGICAL PROCEDURES

Study design

This is a cross-sectional study. The study protocol was prospectively approved by the institutional ethics committee. Prior to data collection, athletes were informed about the procedures and signed the written informed consent.

Participants

The study's proposal was presented and approved by the board members and coaching staff of two AF teams based in Porto Alegre (Brazil) and engaged in the national elite championships. Assessments occurred in the time interval between the state championship (first semester) and national championship (second semester). Both clubs had a similar training routine, which comprised 3 weekly training sessions within the pitch. In addition, specific strength training programs were followed by players according to their playing positions.

To be included in the study, athletes should be > 18 years old, federated, and presenting a regular participation in the club's training routine for at least four months. Athletes could not present recent history of musculoskeletal injuries that could compromise their performance on the tests or recent history of any health conditions that had drawn them from their sport activities for > 30 days within six months prior to the tests.

Procedures

All tests were performed in a single day, within a room with temperature maintained at 23±1° C and proper lighting. The subjects were instructed not to consume stimulants (e.g., caffeine) within 12 hours prior to tests, not to engage in high intensity physical activity within 24 hours prior to the tests, not to drink alcoholic beverages and not to consume any kind of analgesic and/or anti-inflammatory drugs in the 48 hours prior to tests.

Anamnesis

Identification data, information on sports practice (playing position, experience, preferred lower limb) and health information (medication usage, history of injuries) were collected.

Anthropometric evaluation

Anthropometric measurements of body mass and stature were conducted using a precision scale linked with a stadiometer (Welmy, Brazil). The body fat percentage of athletes was assessed by the bioimpedance method through a BF-900 equipment (Maltron, UK). The four-pole measurement technique was used, and all standard procedures were respected[15].

Isokinetic evaluation

After a 10-min warm-up exercise in a cycle ergometer with self-selected load and cadence, athletes were properly positioned in the isokinetic dynamometer

Biodex System 4 Pro (Biodex Medical Systems, USA). Calibration of the equipment was performed previously to data collection and gravitational correction was performed for each leg prior to testing. To prevent the influence of tests' execution order, half of players initiated the testing protocol by the preferred leg while the other half initiated by the non-preferred leg. Athletes received standardized instructions about the testing protocol and performed a specific warm-up (20 submaximal repetitions at $180°\cdot s^{-1}$). A protocol usually adopted in our laboratory was used for isokinetic assessment[16]. Briefly, volunteers performed two sets of three consecutive maximum contractions of flexion-extension in concentric-concentric mode and two sets in eccentric-eccentric mode at $60°\cdot s^{-1}$. A two-minute rest was fulfilled between each test, and subjects were verbally encouraged during tests to produce maximal strength.

The highest peak torque value obtained in each evaluation mode was selected for statistical analysis. Some players exceeded the maximum capacity of the isokinetic dynamometer in knee extensor eccentric contractions (i.e., 450 N·m). In view of this device limitation, this study does not present results of knee extensors eccentric peak torque. We calculated the conventional ratio (knee flexors concentric peak torque divided by knee extensors concentric peak torque), the functional ratio (knee flexors eccentric peak torque divided by knee extensors concentric peak torque), and the bilateral asymmetry (weaker leg / stronger leg - 1). Although there is no consensus regarding the reference values, this study considered the benchmarks of 0.6[9,17] and 1.0[9,18] for conventional and functional ratios, respectively; and a cut value of 10% for bilateral asymmetry[17].

Statistical Analysis

Data normality was analyzed by Shapiro-Wilk test. Comparisons between playing positions (except for QB and K/P due to the small sample size) were performed using One-Way ANOVA, followed by LSD post-hoc. A significance level of 5% ($\alpha<0.05$) was adopted for all comparisons.

The isokinetic peak torques found in our study for each playing position (except for QB and K/P due to the small sample size) were compared with those reported by Zvijac et al.[5] in a study involving collegiate players assessed in the NFL scouting combine. The effect size (ES) between data from Brazilian players and North-American players was calculated through the Cohen's d. ES values were considered as: "trivial" (ES≤0.2), "small" (ES>0.2), "moderate" (ES>0.6), "large" (ES>1.2), or "very large" (ES>2.0)[19].

RESULTS

This study assessed 72 AF players (see players' characteristics in Table 1). Players acting in distinct playing positions had similar ages. OL presented higher body mass than all other positions; DL were heavier than HB, WR and DB; while LB were heavier than HB and DB. HB were shorter than OL, WR, DL and LB. OL had grater fat percentage than other positions (except DL), while DL were fatter than WR.

Table 2 presents the players' peak torque values. OL obtained knee extensors concentric peak torques of both legs significantly higher than WR and HB, as well as higher than DB at the non-preferred leg. The knee flexors concentric peak torque in the preferred leg did not differ between playing positions, while the non-preferred leg of the OL reached significantly higher values than HB. The OL knee flexors eccentric peak torque was greater than DB in preferred leg and greater than HB in the non-preferred leg.

There were no differences between playing positions for conventional and functional ratios (Table 3). Conventional ratio was below the reference landmark of 0.6[9,17] in 76% of the preferred legs and 83% of non-preferred legs. Functional ratio below the cut point of 1.0[9,18] was found in 94% of both preferred and non-preferred legs. Bilateral imbalances higher than 10%[17] were found in 26% of players for knee extensor concentric peak torque, as well as in 39% and 43% of players for knee flexor concentric and eccentric peak torques, respectively.

Figure 1 presents the comparisons between Brazilian elite players (assessed in our study) and collegiate players from USA (reported by by Zvijac et al.[5]). Brazilian players were weaker than North-Americans in all playing positions for both knee extensor and flexor muscles, as well as had poorer conventional torque ratios. International literature provided no results about the knee flexors eccentric peak torque or functional ratio of AF players for comparison with results of the present study.

Table 1. Characteristics of athletes in each playing position. Results expressed as minimum and maximum values for QB and K/P, and mean±SD for other playing positions.

Position	N	Age (years)	Body mass (kg)	Stature (cm)	Fat percent (%)
QB $	3	18-27	76-86	175-186	14-27
K/P $	2	24-30	84-90	167-174	29-30
OL	13	26±7	123±15 *	183±6	36±10 &
HB	10	28±6	77±7	169±4 #	26±4
WR	11	25±6	82±14	183±10	23±5
DL	11	26±6	106±19**	179±9	31±3 †
LB	10	25±4	98±9 ***	180±6	29±2
DB	12	23±3	80±4	178±5	25±2
Total	72	25±6	94±21	179±8	28±7
p-value	---	0.526	0.000	0.000	0.000

QB = Quarterbacks; K/P = Kickers/Punters; OL = Offensive linemen; HB = Halfbacks; WR = Wide receivers; DL = Defensive linemen; LB = Linebackers; DB = Defensive backs. $ not included in between-positions comparison. * OL > all other positions; **DL > HB, WR and DB; ***LB > HB and DB. # HB < OL, WR, DL and LB. & OL > HB, WR, LB and DB; † DL > WR.

Table 2. Concentric (CON) and eccentric (ECC) peak torques of knee extensors (KE) and knee flexors (KF) in preferred and non- preferred limbs (data presented in Nm). Results expressed as minimum and maximum values for quarterbacks QB and K/P, and mean±SD for other playing positions.

	Preferred limb			Non-preferred limb		
	KE	KF		KE	KF	
	CON	COM	ECC	COM	COM	ECC
QB $	193-312	113-156	175-204	194-300	113-162	150-234
K/P $	268-282	149-179	177-211	284-303	129-162	165-253
OL	327±57 *	164±18	252±41 #	328±60 &	176±71 †	253±40 §
HB	238±41	137±45	205±43	228±27	117±19	185±36
WR	260±39	161±57	223±50	262±51	147±31	230±52

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DL	286±47	167±45	227±26	288±60	143±23	227±51
LB	268±75	145±26	222±38	279±48	157±48	223±51
DB	268±40	135±20	201±28	259±49	133±20	203±31
Total	276±56	152±37	220±40	276±57	146±43	220±47
p-value	0.003	0.174	0.028	0.001	0.029	0.012

QB = Quarterbacks; K/P = Kickers/Punters; OL = Offensive linemen; HB = Halfbacks; WR = Wide receivers; DL = Defensive linemen; LB = Linebackers; DB = Defensive backs. $ not included in between-positions comparison. * OL > HB and WR; # OL > DB; & OL > HB, WR and DB; † OL > HB; § OL > HB

Table 3. Conventional ratio (CR) and functional ratio (FR) in preferred and non-preferred limbs. Results expressed as minimum and maximum values for QB and K/P, and mean±SD for other playing positions.

	Preferred limb		Non-preferred limb	
	CR	FR	CR	FR
QB $	0.47-0.59	0.58-0.97	0.49-0.58	0.69-0.78
K/P $	0.53-0.67	0.63-0.79	0.46-0.53	0.58-0.83
OL	0.51±0.08	0.79±0.15	0.54±0.17	0.79±0.16
HB	0.57±0.15	0.87±0.14	0.52±0.06	0.82±0.13
WR	0.61±0.16	0.85±0.10	0.56±0.04	0.88±0.10
DL	0.59±0.15	0.80±0.08	0.50±0.06	0.79±0.10
LB	0.59±0.22	0.90±0.34	0.58±0.26	0.80±0.11
DB	0.51±0.08	0.76±0.10	0.52±0.07	0.80±0.13
Total	0.56±0.14	0.82±0.17	0.54±0.13	0.81±0.12
p-value	0.398	0.363	0.773	0.535

QB = Quarterbacks; K/P = Kickers/Punters; OL = Offensive linemen; HB = Halfbacks; WR = Wide receivers; DL = Defensive linemen; LB = Linebackers; DB = Defensive backs. $ not included in between-positions comparison.

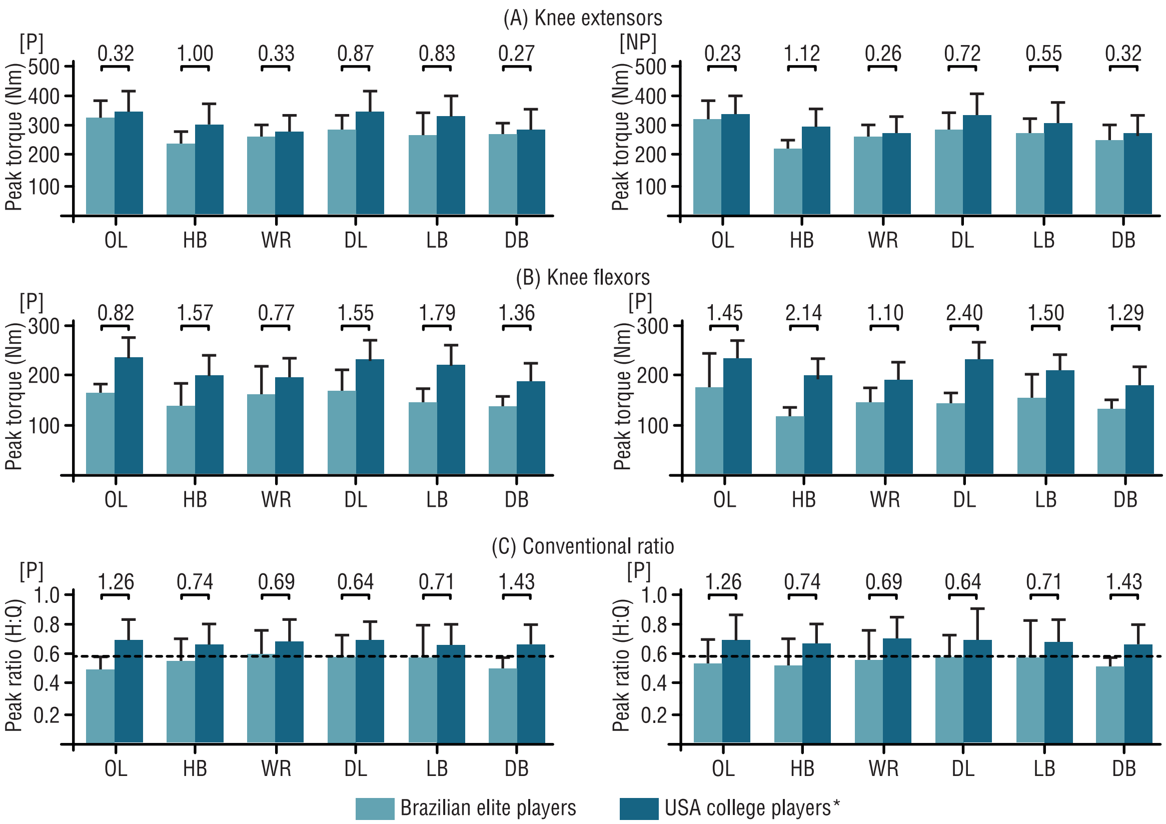

Figure 1. Comparison between Brazilian and North-American players for knee extensors concentric peak torque (A), knee flexors concentric peak torque (B), and conventional torque ratio (C). Results expressed as mean±SD for other playing positions. Effect sizes are presented over the brackets: "trivial" (ES≤0.2), "small" (ES>0.2), "moderate" (ES>0.6), "large" (ES>1.2), or "very large" (ES>2.0). OL = Offensive linemen; HB = Halfbacks; WR = Wide receivers; DL = Defensive linemen; LB = Linebackers; DB = Defensive backs. [P] preferred limb; [NP] non- preferred limb. * Data extracted from Zvijac et al.[5]

DISCUSSION

This study seems to be the first one to report the isokinetic profile of the knee extensor and flexor muscles of AF players outside the USA, the country that holds the hegemony of the sport. In short, our findings suggest that: (1) thigh muscle strength levels are different among the playing positions of AF; (2) Brazilian players present high incidence of muscle strength imbalances; and (3) Brazilian players are below the North-Americans in relation to torque production capacity of thigh muscles.

Physical biotype is one of the determining factors for high performance in AF[4,20–22]. Therefore, call attention the dissimilar body mass and stature found in Brazilian players compared to collegiate[21,23] and professional athletes[20,22] from USA. An interesting study developed by Anzell et al.[21] has documented the changes in body proportions of collegiate and professional players of AF in USA throughout the years 1942 to 2011. The average stature of Brazilian players (1.79 m) is similar to the average stature of collegiate players at 1960's, and this low stature has never been observed among NFL athletes[21]. The average body mass of Brazilian players (94 kg) is near to the values from 1980's and 1950's of collegiate and professional athletes, respectively[21]. In other words, these data suggest that the Brazilian players still need to evolve their body size to equate the world elite AF players. In addition, Brazilian players seems to have a higher fat percent than North-American players, but careful is recommended on this conclusion because North American studies used skin folds[22], radiographic absorptiometry dual energy[23] and plethysmography displacement air[20] to assess the players' fat percent, while we used the bioimpedance technique.

The smaller body size represents a possible reason why players engaged in the elite competition level of Brazil had lower torque production capacity than collegiate players in USA[5]. However, the dissimilar level of conditioning may be the main factor behind these findings. AF is an amateur sport in Brazil, and even players from elite teams usually train only 3-4 times per week. Brazilian teams do not have specific facilities. Teams usually train in fields within public parks or fields borrowed by the town hall or universities, and depend of commercial partners to assess gyms and medical support. On the other hand, players acting at the National Collegiate Athletic Association (NCAA) has a semi-professional routine. Universities provide all facilities (training fields, gyms, etc.) and teams have specialized coaches, conditioning trainers and a full medical staff to develop their players. These specific scenarios should be taking in account when AF players from USA are compared with those ones from other countries.

Prospective studies have demonstrated that strength imbalances between knee flexor and extensor muscles significantly increases the risk of hamstring strains in Australian football[24] and soccer[10] athletes, as well as potentially contributes to knee instability and predisposes to knee sprains[9]. Due to the high incidence of injuries in knee joint and hamstring muscles in AF[6–8], strength balance between the thigh muscles is an important point when it comes to injury prevention. In this sense, our findings revealed that more than 3/4 of Brazilian players had a deficient conventional ratio, and this prevalence increased to 94% when considering the functional ratio, suggesting these players have weak hamstring muscles. Interestingly, the USA collegiate players[5] have average values of conventional ratio above 0.6 in all playing positions (Figure 1-C), suggesting that their training system seems to lead to musculoskeletal adaptations that draw players from the risk zone. Unfortunately, the lack of results in the literature involving the functional ratio of North American athletes leaves open the question about their knee flexors eccentric capacity, while our results demonstrated a notably deficiency in knee flexors eccentric torque of Brazilian athletes.

The high number of athletes below the recommended standards for conventional and functional ratios suggests that efforts must to be made for balancing the torque production capacity of the knee flexor and extensor muscles and help to prevent future injuries. Petersen et al.[25] and Seagrave III et al.[26] have implemented training programs to restore muscle balance between the anterior and posterior thigh muscles on soccer and baseball players, respectively. Their training protocols involving the Nordic hamstring exercise have been proven effective in preventing primary and recurrent hamstring injuries[25], as well as in reducing the total number of days missed due to injury[26]. Therefore, Nordic hamstring exercise could be recommended as an interesting choice for athletes with muscle imbalance assessed in our study.

Strength balance among right and left limbs is related to sports performance and injury risk[27]. The considerable number of athletes with a bilateral asymmetry higher than 10% is perhaps related to the higher demands placed on one of the lower limbs during the sport practice. An example is the initial action of the defensive and attack players, when one leg (right or left, according to individual preference) is used for the initial impulse of the race against the opponent or towards the opposing field in every move of the match. Compensation strategies should be implemented in the weakest to restore the strength symmetry on the right and left legs.

Like other studies with AF, the low number of QB and K/P may be considered a limitation of this study. This small sample size prevents a reliable statistical comparison with players from other playing positions, as well as isokinetic comparison with QB and K/P assessed by Zvijac et al.[5]. On the other hand, a positive aspect of this study was the total sample size (72 players), which is higher than most studies comprising isokinetic evaluation of AF players. Future investigations should verify how much the strength imbalances reported here affect the incidence of injuries in AF players.

CONCLUSION

AF elite athletes in Brazil have specific isokinetic performances of knee flexor and extensor muscles according to their playing position, and Brazilian players have clear disadvantage compared to elite university players from USA. The literature gap regarding AF played around the world precludes a comparison with athletes from other countries, but our findings represent a new benchmark for leagues outside the USA. Additionally, a considerable number of players presented hamstring-to-quadriceps strength imbalance and/or bilateral strength asymmetry. As a practical application, these findings denote that specific training programs should be designed and implemented to improve strength and restore the muscle strength balance in lower limbs of AF players from Brazil.

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