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ORIGINAL INVESTIGATION

A Comparison of Training With a Velocity Loss Threshold or to Repetition Failure on Upper-Body Strength Development in Professional Australian Footballers

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Purpose: To compare resistance training using a velocity loss threshold with training to repetition failure on upper-body strength parameters in professional Australian footballers. ***Methods:*** A total of 26 professional Australian footballers (23.9 [4.2] y, 189.9 [7.8] cm, 88.2 [8.8] kg) tested 1-repetition-maximum strength (FP_{max}) and mean barbell velocity at 85% of 1-repetition maximum on floor press (FP_{vel}). They were then assigned to 2 training groups: 20% velocity loss threshold training (VL; n = 12, maximum-effort lift velocity) or training to repetition failure (TF; n = 14, self-selected lift velocity). Subjects trained twice per week for 3 weeks before being reassessed on FP_{max} and FP_{vel}. Training volume (total repetitions) was recorded for all training sessions. No differences were present between groups on any pretraining measure. ***Results:*** The TF group significantly improved FP_{max} (105.2–110.9 kg, +5.4%), while the VL group did not (107.5–109.2 kg, +1.6%) ($P > .05$). Both groups significantly increased FP_{vel} (0.38–0.46 $m{\cdot}s^{-1}$, +19.1% and 0.37–0.42 $m{\cdot}s^{-1}$, +16.7%, respectively) with no between-groups differences evident ($P > .05$). The TF group performed significantly more training volume (12.2 vs 6.8 repetitions per session, $P > .05$). ***Conclusions:*** Training to repetition failure improved FP_{max}, while training using a velocity loss threshold of 20% did not. Both groups demonstrated similar improvements in FP_{vel} despite the VL group completing 45% less total training volume than the TF group. The reduction in training volume associated with implementing a 20% velocity loss threshold may negatively impact the development of upper-body maximum strength while still enhancing submaximal movement velocity.

Keywords: linear position transducer, velocity-based training, preseason, concurrent training, training dose response

Australian football is a contact sport that involves athletes performing repeated bouts of high-intensity activity (eg, sprinting, jumping, tackling) interspersed with periods of lower-intensity movements (eg, jogging, walking).[1] While aerobic endurance is a central determinant of performance due to the extreme running demands of the game,[2] high levels of strength are also required to perform a variety of movements such as bumping, tackling, wrestling, and fending off opponents when contesting possession.[2,3] Upper-body strength is positively related to team selection in elite junior players,[4] while strong associations have been reported between 1-repetition maximum (1RM) bench press and a number of in-game statistics, such as contested possessions, hard ball gets, physical pressure acts, and clearances for certain positions in elite senior players.[5] From a performance enhancement perspective, the development of upper-body strength and power qualities in Australian Football League footballers would appear intuitive.

Traditionally, effective strength program design involves the manipulation of training variables, such as training intensity, volume, rest periods, and exercise selection.[6] However, in recent years, a number of velocity-based training methods have evolved in which velocity has become an important variable in the programming process.[7] Based on the observation that barbell velocity loss across repetitions occurs in a predictable linear pattern when concentric actions are performed with maximal intent,[6,8] coaches can now accurately quantify the acute level of fatigue during a set in real time and utilize this metric to regulate training stress. One such method involves the use of velocity loss thresholds whereby an athlete terminates a set once a predetermined level of barbell velocity loss has occurred.[9] This approach facilitates athletes training at higher average movement velocities and may better stimulate rapid force production adaptations,[9] as it has been demonstrated that actual movement velocity of training influences subsequent neuromuscular responses.[10] This method also potentially reduces the risk of overtraining by reducing the acute metabolic stress, hormonal response, muscle damage, and overall fatigue induced by traditional methods like training to repetition failure.[11,12]

To date, the use of low velocity loss thresholds (15%–20% range) have been reported to be equally or more effective than high velocity loss thresholds (30%–40% range) for optimizing training volume, movement speeds, and subsequent gains in lower body strength and power measures in resistance-trained males[9] and male professional soccer players.[12] Significant gains in upper-body strength have been reported in resistance-trained males employing a 20% velocity loss threshold after 3 weeks of training, but not in those training to repetition failure.[13] To date, no studies have investigated the effect of velocity loss thresholds on upper-body strength in athletic populations. Given the often extreme physical demands involved in preparing for professional sports, investigating the efficacy of training methods that could potentially induce positive adaptations in strength and movement velocity while reducing unnecessary training stress is warranted in a cohort of professional athletes.

Therefore, the purpose of the current study was to investigate the effects of 3 weeks of resistance training with a 20% velocity loss threshold versus repetition failure on upper-body strength in

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professional Australian footballers. It was hypothesized that training with a velocity loss threshold would lead to similar or superior gains in maximum strength and submaximal movement velocity compared with training to repetition failure.

Methods

Subjects

A total of 28 professional footballers from one senior football team playing in the Australian Football League participated in the study, which was conducted during their regular preseason training program (see Table 1). Two subjects were forced to drop out due to injuries incurred during on-field sessions. Therefore, 26 subjects completed the study (mean [SD]; age: 23.9 [4.2] y; height: 189.9 [7.8] cm; body mass: 88.2 [8.8] kg; senior games played: 70.5 [18]). The inclusion criteria required all subjects to be healthy and to have been engaged in continuous resistance training for a minimum of 1 year prior to the study start date. Based on previous research assessing velocity loss thresholds in resistance-trained individuals,[13] a large effect size (ES) was anticipated for the between-group differences for the primary variable (upper-body strength). Therefore, with a power level of $1-\beta=0.80$, the minimum sample size was deemed to be 12 participants per group.[14] Approval for the research was granted by the human research ethics committee of the University of Technology Sydney.

Design

This study employed a nonrandomized, parallel group, pre–post experimental design to compare the effects of 3 weeks of training with a 20% velocity loss threshold or training to repetition failure on measures of upper-body strength. All subjects were tested for upper-body strength (1RM floor press [FP_{max}]) and submaximal lift velocity (maximum effort velocity test at 85% of their established 1RM [FP_{vel}]). They were then assigned to one of 2 training groups (velocity loss threshold [VL] or training to repetition failure [TF]), in which they performed 2 sessions of upper-body pressing per week for 3 weeks. Five days after the completion of the training, all participants were retested, and the results were analyzed for any differences in strength, movement velocity, and training volume (repetition count) between the groups. All testing and training were performed as part of scheduled preseason strength training sessions (see Table 1). Posttesting occurred at the first strength session of the week to ensure that all subjects had 2 days of rest immediately prior. All subjects received an identical protein supplement immediately after all strength training sessions. No other nutritional supplement strategies were employed for the duration of the study.

Procedures

Football Training and Conditioning. Total training time and total running distance were recorded using global navigation satellite system (GNSS) units sampling at 10 Hz (Optimeye S5; Catapult Sports, Melbourne, Australia). Intraclass correlation coefficients (ICCs) for Catapult GNSS devices have demonstrated high to very high reliability ($r=.86$–.99) for distances covered at low-, high-, and very high-speed running intensities.[15]

Anthropometry. Body mass was recorded using a calibrated portable digital scale (Tanita, Wedderburn, Japan) to the nearest 0.01 kg, with players advised to remove footwear and wear light fitting clothing. Height was measured from the floor to the top of the skull using a portable stadiometer (Ecomed; Seca, Sydney, Australia) and measured to the nearest 0.1 cm.

Upper-Body Strength. The floor press exercise was selected for familiarization purposes, because this was the primary measure of upper-body strength used by the team and all subjects were well-trained in the movement (floor press training experience: 3.3 [1.3] y). FP_{max} testing was performed following a standardized warm-up. The subjects performed an initial set of 5 repetitions at 60% of their estimated 1RM (based upon recent training history and previous maximum test results). Load was increased to 75% for 3 repetitions, 85% for 2 repetitions, and 95% for 1 repetition. At this stage, the researcher dictated incremental load increases until 1RM was achieved with correct technique allowing 4 to 5 minutes of rest between each attempt. The exercise was performed with legs straight and no hip lift was permitted. Subjects were instructed to lower the barbell with control until their elbows touched the floor, pause in the bottom position for a 2-second count verbally controlled by the lift spotter, and then press the barbell to full lockout without assistance. The FP_{max} procedure displayed excellent levels of test–retest reliability when 13 players were assessed twice over a 2-week period ($ICC_{2,1}=.99$; 95% confidence interval, .98 to 1.00).

Velocity. Mean barbell velocity was measured using a linear position transducer (GymAware PowerTool; Kinetic Performance Technology, Canberra, Australia) attached to the loading sleeve of the barbell. This system has previously been reported to provide valid measures of mean concentric barbell velocity,[16] while the specific FP_{vel} testing procedure used in the current study revealed an excellent level of test–retest reliability when 11 players were assessed twice over a 2-week period ($ICC_{2,1}=.91$; 95% confidence interval, .65 to .98). Following the FP_{max} test, subjects were given a 5-minute rest before establishing their mean FP_{vel} by performing one set of 2 repetitions at 85% of their 1RM. Subjects were instructed to pause for 2 seconds in the bottom position before vertically pressing the barbell concentrically as quickly and explosively as possible across the full range of motion to full lockout. Performing a 2-second pause prior to the concentric portion of a lift has previously been shown to improve reliability during isoinertial

Table 1 Overview of Weekly Preseason Training Program

Time of day	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7
AM	FT and PC (2–3 h)	FT and PC (1–2 h)	FT and PC (2–3 h)	FT (1–2 h)	FT and PC (2–3 h)	Off	Off
PM	ST 1[a] (1 h)		ST 2[a] (1 h)		ST 3 (1 h)		

Abbreviations: FT, football training; PC, physical conditioning; ST, strength training.
[a]Specific ST sessions in which testing and training occurred.

strength testing.[17] Strong verbal encouragement and velocity feedback were provided, because this has been shown to improve athlete motivation and performance in strength tasks that involve measuring movement velocity.[18] The fastest of the 2 repetitions was used for further analysis. To enable direct comparison, velocity testing was performed at the same absolute load following the training period (85% of pretest FP_{max}). There was one minor difference in testing order at the posttest. Because the test load was already established from pretesting, the posttest FP_{vel} was performed during the warm-up progression and not following the establishment of the 1RM. To ensure fatigue had not negatively impacted the pretesting FP_{vel}, individual pretest velocity was reset at the first training session if a subject exceeded their pretesting score.

All upper-body strength and velocity testing was performed under the direct supervision of the lead investigator at the same venue and at the same time of day for each subject (±2 h).

Training Interventions

The descriptive characteristics of the resistance training programs are presented in Table 2. Gym sessions were performed in the afternoon and were always preceded by field-based skills and endurance training followed by a 3-hour recovery period. All strength sessions were supervised by the lead investigator (UK Strength and Conditioning Association–accredited coach). Floor press was performed twice per week for the 3-week duration of the study, similar to previous velocity loss threshold protocol design.[13] All floor press repetitions were paused for 2 seconds in the bottom position as per the test protocol. Rest periods of 3 to 4 minutes were prescribed between sets. No other pressing movements were performed for the duration of the project. Lift volumes and relative lift intensities were identical for both groups on all other strength exercises performed as part of the preseason strength program.

A nonrandomized procedure was used for allocating the training groups due to the logistical demands associated with a professional sports team. Groups were selected based on program scheduling priorities (positional/tactical meetings, etc); however, all specific football training and conditioning programs were controlled for load and were homogenous between the groups for the duration of the study.

TF Group. Failure was defined as the subject being unable to perform another repetition without assistance. No velocity monitoring was performed and subjects were instructed to perform the concentric phase of movement at their normal, self-selected speed. The total number of repetitions performed on all work sets at 85% 1RM was recorded.

VL Group. All sets were performed with real-time velocity feedback provided using linear position transducers (GymAware PowerTool; Kinetic Performance Technology). Individual velocity loss thresholds for training were set at 20% below the fastest repetition from their pretest FP_{vel}.[13] Once a repetition was performed below this threshold velocity, the participant was alerted via an auditory tone and the set was immediately terminated. The total number of repetitions performed on all work sets at 85% 1RM was recorded, with the final repetition of each set in which the participant failed to achieve the required velocity being included in this value.

Statistical Analysis

For all variables, values are presented as mean (SD). The SEM was also calculated using the formula: SEM = SD/(1 – ICC)$^{-2}$. In addition, t tests were completed to examine baseline intergroup differences (independent samples test), and pre-to-post intragroup football training and conditioning volumes (paired tests). Data were analyzed using a 2 × 2 (time × group) factorial analysis of variance. If a significant interaction effect was present, paired sample t tests were completed to examine pretraining to posttraining intragroup differences. Differences in repetition count from the first week to the final week of training were examined using paired sample t tests for the intragroup analyses and independent sample t tests for the intergroup comparisons. The minimum effective dose for the training was examined by correlating the average session training volume and the percentage change in strength elicited from the training program. Linear regression analysis yielded equations for the slopes of the trend lines of each condition to enable comparisons between training methods. The ESs were calculated using partial eta squared (η_p^2) for the factorial analysis of variance with magnitudes defined as small (<.06), moderate (.06–.14), and large (>.14). Cohen d was calculated to quantify the ES for intragroup differences and classified as small (<0.50), moderate (0.50–0.79), and large (>0.80).[19] Data analysis was completed using SPSS (version 25.0; SPSS, Chicago, IL), and statistical significance for all tests was set at $P < .05$.

Results

Baseline

There were no significant differences between the TF and VL groups reported before training for any variables.

Football Training and Conditioning

No differences were recorded between groups for total training time ($P = .50$) or total running distance ($P = .50$) over the course of the study.

Table 2 Overview of the 2 Training Programs

	Warm-up sets			Work sets		
Group	Set 1	Set 2	Set 3	Set 4	Set 5	Lift instructions
Training to failure	5 at 55% 1RM	5 at 65% 1RM	5 at 75% 1RM	Maximum repetitions at 85% 1RM	Maximum repetitions at 85% 1RM	Self-selected lift velocity for all sets and repetitions
Velocity loss	5 at 55% 1RM	5 at 65% 1RM	5 at 75% 1RM	Maximum repetitions ≥20% velocity loss at 85% 1RM	Maximum repetitions ≥20% velocity loss at 85% 1RM	Maximum concentric effort for all sets and repetitions

Abbreviation: 1RM, 1-repetition maximum. Note: Sessions were performed 2 times per week for 3 weeks (total of 6 resistance training sessions).

Body Mass

Body mass remained unchanged from pretesting to posttesting in the TF and VL groups (Table 3).

Strength

A significant main effect for time was reported for FP_{max} ($P > .01$, $\eta^2 = .43$). A significant group × time interaction effect was evident between training groups ($P = .03$, $\eta^2 = .19$), with training resulting in significant increases in maximum strength for the TF group ($P > .01$) but not for the VL group ($P = .07$) (Table 3). A moderate ES was reported for the improvement in strength in the TF group and a small ES for the changes in the VL group (Table 3).

Velocity

There was no group × time interaction effect evident between training groups ($P = .63$, $\eta^2 = .01$). A significant main effect for time was reported for FP_{vel} ($P > .01$, $\eta^2 = .52$), with training resulting in significant increases in FP_{vel} for the TF group ($P > .01$) and the VL group ($P > .01$) (Table 3). A large ES was reported for both groups for this variable (Table 3).

Training Volume

The TF ($P > .01$) and VL groups ($P = .03$) both significantly increased the total number of repetitions performed per set from week 1 to week 3 (Table 3). The total repetitions completed per training session were also different between groups for week 1 ($P > .01$) and week 3 ($P > .01$), with the TF group recording higher values. As demonstrated in Figure 1, there was a tendency for a greater change in strength with a greater number of repetitions completed during training. Based on the *y* intercept and positive gradient of each plot, an effective minimum training dose appears to exist for both conditions.

Discussion

The main finding of this study was that short-term resistance training in professional Australian footballers using a 20% velocity loss threshold did not lead to a significant increase in FP_{max}, while training to repetition failure did. Interestingly, both methods of training increased FP_{vel}, despite the velocity loss threshold group performing 45% less total training volume. To our knowledge, this is the first time the efficacy of using a velocity loss threshold protocol has been investigated on measures of upper-body strength in professional team sports athletes.

Contrary to our hypothesis, resistance training utilizing a 20% velocity loss threshold did not increase FP_{max} (+1.6%), while training to repetition failure led to an improvement (+5.4%) (Table 3). Training to failure may allow recruitment and overload of a larger pool of active motor units, potentially leading to greater strength development,[20] while the increased metabolic stress, hormone response, and muscle damage involved may mediate hypertrophic adaptations.[21] While no changes in body mass occurred, a more detailed anthropometric assessment would be required to ascertain whether the FP_{max} increase occurred independently of muscle hypertrophy. The magnitude of strength gains in the TF group was consistent with the findings of Drinkwater et al,[20] who reported a 9.6% increase in bench press 1RM after 6 weeks of training to failure in elite junior basketball and soccer players. This rate of improvement was similar to the current study when the longer time frame involved was taken into account.

The absence of strength changes for the VL group was in contrast to the findings of Padulo et al,[13] who reported a 10.2% increase in 1RM bench press using a 20% velocity loss threshold in resistance-trained males. Training mode, lift intensity, velocity loss threshold, frequency, and program duration were all similar to the current study. However, total training volume did differ, with the current study utilizing a lower number of work sets per session (2 fixed work sets) as opposed to continuous sets until subjects were unable to complete a single effective repetition under either condition.[13] This difference may have contributed to the contradictory findings between the studies and potentially highlights that an inverted U-shaped relationship may exist between training volume and subsequent strength adaptations.[12] While 2 work sets may be sufficient to stimulate strength gains after 3 weeks of training when the sets are performed to failure, it may not provide an adequate training volume to stimulate strength gains when utilizing a 20% velocity loss threshold and concurrently undertaking endurance training. The existence of population-specific dose–response relationships with respect to training volume and strength development in untrained, recreationally trained, and trained athletic cohorts have previously been identified.[22] Given the focus on movement velocity, the 2 work set protocols utilized by

Table 3 Descriptive Characteristics and Statistical Information for the Training-to-Failure and Velocity-Loss-Threshold Training Groups Prior to and Following the Training Program

	Training to failure group				Velocity loss group			
Variable	Pretest	Posttest	P	ES (95% CI)	Pretest	Posttest	P	ES (95% CI)
Body mass, kg	88.6 (9.4)	88.6 (9.2)	.81	0.00 (−0.78 to 0.78)	87.7 (8.4)	88.0 (7.9)	.14	0.04 (−0.81 to 0.88)
Floor press 1RM, kg	105.2 (9.4); 0.94	110.9 (10.8)*; 1.08	.002	0.57 (−0.21 to 1.34)	107.5 (5.7); 0.57	109.2 (5.8); 0.58	.07	0.29 (−0.56 to 1.14)
Floor press 85% 1RM mean velocity, $m \cdot s^{-1}$	0.38 (0.05); 0.015	0.46 (0.09)*; 0.026	.002	1.10 (0.30 to 1.85)	0.37 (0.04); 0.013	0.42 (0.05)*; 0.014	.001	1.33 (0.49 to 2.19)
	Week 1	**Week 3**			**Week 1**	**Week 3**		
Average repetitions per session at 85% 1RM	11.3 (3.3)	13.2 (3.7)	<.01	0.55 (−0.23 to 1.32)	4.4 (1.2)	5.1 (1.8)	.03	0.48 (−0.39 to 1.30)

Abbreviations: 1RM, 1-repetition maximum; CI, confidence interval; ES, effect size. Note: Values are presented as mean (SD); SEM.
*Significantly different from pretest.

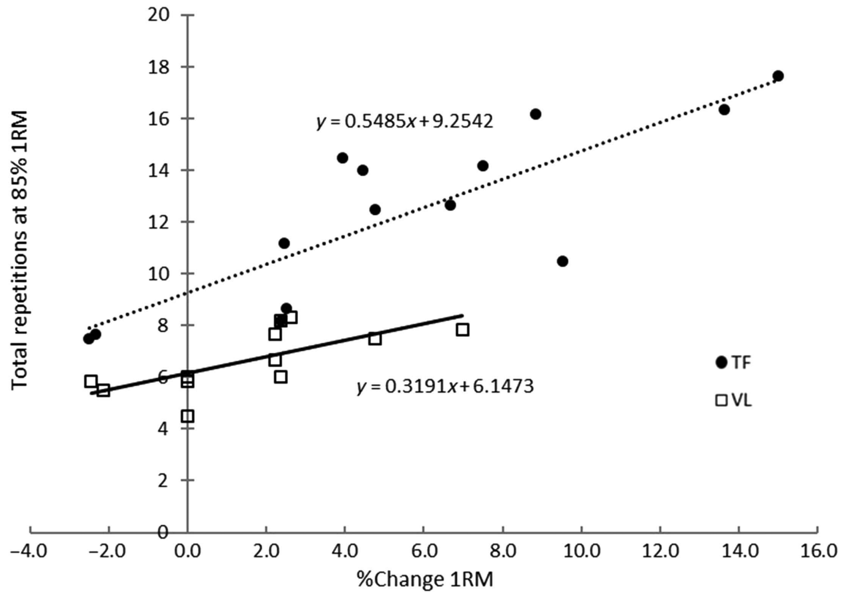

Figure 1 — Average repetitions performed per session at 85% 1RM over the course of the 3-week training program relative to individual change in strength. 1RM indicates 1-repetition maximum; TF, training-to-repetition-failure group; VL, velocity-loss-threshold group.

the VL group in the current study did not meet the mean training volume required to maximize strength gains for a trained athletic population.[22] Examination of the individual training volume data in conjunction with the information pertaining to strength changes (Figure 1) also highlights that a minimum effective training volume for each training condition may exist. Future research should aim to scrutinize this aspect of velocity-based training more closely.

The VL and TF protocols both resulted in a significant increases in FP_{vel} (+16.7% and +19.1%, respectively), with large ESs for both conditions ($d = 1.33$ and 1.11, respectively). The increase in FP_{vel} for the TF group may be partially explained by the increase in FP_{max}, resulting in a reduction in the relative intensity that the pretest 85% 1RM load represented. However, the improvement in FP_{vel} in the VL group occurred independent of a change in maximum strength. Furthermore, this increase in submaximal lifting velocity occurred despite the VL group performing 45% less training volume per session than the TF group. This finding is similar to previous research assessing velocity adaptations to velocity loss threshold training in untrained males.[9] Specifically, it has been reported that training groups using 20% or 40% velocity loss thresholds across a range of loads for 8 weeks on back squats both significantly increased mean propulsive velocity at heavy loads (+12.7% vs +13.7%) despite the 20% velocity loss group actually performing 40% less total training volume.[9]

While the professional status of the athletes involved in the current study gives unique insight into the adaptation of elite-level field sport athletes to velocity-based training methods, being able to perform such research comes with a number of practical limitations due to the logistical and performance demands of a professional football program. For instance, because all subjects were involved in a preseason training phase, they were required to concurrently train strength and endurance qualities, which may have compromised the strength and/or velocity adaptations of both groups.[23] Due to scheduling constraints of the football program, it was also not possible to randomize the training group allocation, although no differences were reported between groups on any outcome measures at pretesting. Finally, it can be argued that the relatively short program duration (3 wk) may not have provided sufficient training time for increases in maximum strength to manifest using a 20% velocity loss threshold. However, significant 1RM strength gains in bench press have been reported previously over a similar time frame,[13] and both groups did significantly improve FP_{vel} in the current study. It is also worth noting that compliance was 100% for all subjects, ensuring training exposure was maximized despite the constraints of the study design.

Practical Applications

This study suggests that resistance training to repetition failure can be an effective method to optimize upper-body maximum strength during a short, intensive preseason training block. In contrast, the evident velocity adaptations imply that strength and conditioning coaches can continue to stimulate strength-speed adaptations with significantly reduced training volumes when a 20% velocity loss threshold is utilized. This may be particularly relevant during short peaking phases or during intensive competition blocks when athletes have less available time to train in the weight room and practitioners attempt to minimize excessive fatigue. Finally, while the use of a 20% velocity loss threshold did not improve maximum strength, further research into velocity loss threshold strategies is warranted in order to better understand specific dose–response dynamics.

Conclusions

A 3-week training program incorporating a velocity loss threshold did not increase upper-body FP_{max} in professional footballers, while training to repetition failure did lead to an improvement. Furthermore, while both training modalities enhanced FP_{vel}, the velocity loss threshold group achieved this adaptation despite performing significantly less total training volume than the training to repetition failure group. These findings have implications for strength and conditioning practitioners looking to implement velocity loss threshold training methods with athletic populations.

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