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Injuries in Women Associated With a Periodized Strength Training and Running Program

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ABSTRACT

Forty-five women participated in a 24-week physical training program designed to improve lifting, load carriage, and running performance. Activities included weightlifting, running, backpacking, lift and carry drills, and sprint running. Physicians documented by passive surveillance all training-related injuries. Thirty-two women successfully completed the training program. Twenty-two women (48.9%) suffered at least 1 injury during training, but only 2 women had to drop out of the study because of injuries. The rate of injury associated with lost training time was 2.8 injuries per 1,000 training hours of exposure. Total clinic visits and days lost from training were 89 and 69, respectively. Most injuries were the overuse type involving the lower back, knees, and feet. Weightlifting accounted for a majority of the lost training days. A combined strength training and running program resulted in significant performance gains in women. Only 2 out of 45 participants left the training program because of injuries.

Key Words: women, lifting, load carriage, injury visits

Reference Data: Reynolds, K.L., E.A. Harman, R.E. Worsham, M.B. Sykes, P.N. Frykman, and V.L. Backus. Injuries in women associated with a periodized strength training and running program. *J. Strength Cond. Res. 15(2):136–143. 2001.*

Introduction

Since 1978, women have been permitted to enter regular Army units, and the proportion of women in the U.S. Army has increased from 9.6% in 1983 to 13.5% in 1996 (13). Currently, 38% of the military occupational specialties (MOS) or jobs available to women have physically demanding tasks in the ''very heavy'' category defined as occasional lifting over 100 lb and frequent lifting in excess of 50 lb (2). Studies have shown that women soldiers cannot lift as much weight compared with men soldiers (10, 11). Also, prior to basic training only a small percentage of women can perform physically demanding lifting tasks (15).

Army basic training is not considered a strength-training program and may only increase lifting capability by 8–12% (15). This has prompted the evaluation of resistance exercise programs to determine if load carriage and lifting loads to certain heights can be improved in women soldiers (8). Knapik et al. (7) conducted a 14-week, nonperiodized, combined resistance and running program with women soldiers and reported a 17% increase in ability to lift 15 kg as many times as possible in a 10-minute time period.

Little data are available on injuries in women participating in combined resistance and aerobic programs. Knapik et al. (7) reported an injury incidence of 28.5% in their training program. Either a physical therapist or physician diagnosed all of the injuries. Medical personnel recorded as an injury any musculoskeletal complaint that persisted for several training sessions. The injuries were soft tissue musculoskeletal complaints. A total of 7 study-related injuries were recorded, of which 4 were recurrences of injuries that developed before the study. The 7 injuries were associated with either weight training or running. Two out of 21 women were dropped from the study because of training-related injuries.

Clark et al. (1) provided an overview of injuries in collegiate women athletes (they extrapolated from 89,086 participants), which were reported to the National Athletic Injury/Illness Reporting System (NAIRS) during 3 years (1975–1978). The study reported rates of injuries associated with lost training time as injuries per 1,000 hours of exposure. Among contact and noncontact sports, the rate for basketball was 2.5, and for track and field it was 2.2.

In the present study, we report the incidence and distribution of injuries associated with a rigorous 24-week physical training program designed to improve lifting, load-carriage, and running performance in women (3). Identifying incidence and types of injuries associated with these specialized resistance programs is important for medical planning to support these training activities (4, 5).

Methods

Subjects

Participants were 45 women (44 civilian, 1 military) who gave their written informed consent to engage in a 24-week physical training program designed to increase strength, endurance, and load-carriage ability. This program is described in detail by Harman et al (3).

Height and body mass were measured pre-, mid- (14th week), and posttraining. Percent body fat was calculated pre- and posttraining using dual-energy X-ray absorptiometry (DEXA; Lunar software, version 3.6, Madison, Wisconsin). Pre-, mid-, and posttraining tests were conducted to measure strength, aerobic fitness, and load-carriage abilities.

Group Attrition Data

Of the 45 participants who began the training program, 13 women (28.8%) did not complete all 24 weeks of training. In the early weeks of the study, 4 women left, and 9 left in the final weeks. Only 2 women dropped out because of training-related injuries. The remaining 11 women left because of personal (e.g., childcare conflicts) and non–study-related health issues (2 pregnancies).

Training Program

Strength and conditioning specialists certified by the National Strength and Conditioning Association designed the training regimen. The purpose was to increase strength and muscular endurance to improve lifting and load-carriage ability. The 24-week program consisted of training 5 days per week, with each session lasting 1–1.5 hours (Table 1). Participants were permitted to miss up to 10 days during the 24 weeks (3).

The weight-training portion was initially performed 4 days per week (Table 2) and then later reduced to 2 days per week using a periodization model (see Table 3; 14). As strength increased, repetitions per set were decreased and the weight increased, with training intensity peaking during week 14 of training. Repetitions were then increased and weights decreased, followed by a progressive decrease in repetitions and increase in weight throughout the last few weeks of the training program.

The aerobic program consisted of running, backpack hiking, and specialized drills. The aerobic prescription was "very difficult effort level." Following weightlifting and a 10-minute rest period, women ran 3.2 km twice weekly. Interval training was added after week 8.

Participants hiked 8 km once per week at a minimum pace of 6.4 $km \cdot h^{-1}$ but were allowed to go faster. The load was initially 0 kg and was gradually increased 2–3 kg per week if they successfully maintained at least the 6.4 $km \cdot h^{-1}$ pace the previous week. To reduce the likelihood of overuse injury, the load was not increased beyond 34 kg for any of the volunteers, even for those who could maintain the required pace with that load.

After week 8 of training, special drills were added. These activities included running hills and interval training with and without loads, jumping with loads, and lift and carry tasks.

Injured women performed alternative aerobic exercises (e.g., stationary cycling). They then returned to the standard aerobic activities when medically cleared.

Testing Battery

A 2-week test battery was conducted before training, after 14 weeks of training, and at the end of training. Tests included those for maximal oxygen uptake ($\dot{V}O_2max$), vertical and standing long jumps, muscular strength and endurance using free weights, maximal lifting and carrying tasks, and load-carriage speed. These procedures are described in Harman et al (3).

Demographic Questionnaire

All women ($n = 45$) were given a questionnaire that contained inquiries about education level, occupation, exercise history, competitive sports participation, tobacco use, alcohol consumption, and reproductive history. Women were asked if they had participated in strength and aerobic exercises for at least 6 months before the study and, if so, the frequency of the activities per week. Individuals were questioned if they had smoked cigarettes within the past year and, if so, for how long they had smoked. Inquiries were made about the number of alcoholic beverages consumed per week within the past year. Individuals were also asked about childbearing history, contraceptive use, and menstrual history.

Medical Data

Injury data were collected by passive surveillance techniques. If a woman suffered an injury during training, the trainer while on-site recorded the injury and referred her to the study physician. The physician would evaluate the injury and provide treatment and, if necessary, refer her to a physical therapist or orthopedic physician. All training-related injuries were documented in each individual's medical record. The date, type and site of injury, and training activity were documented, as well as the disposition. Clinic visits to physical therapy and orthopedic specialists were also recorded. A physician and experienced technician reviewed all medical records ($n = 45$) at the end of the study. Attempts were made to verify the official diagnosis and associated training activity of each case.

For this study, the injury definitions included train-

Table 1. Training program overview.

Day of week	Type of exercise	Duration of exercise	Special notes
Monday	Upper- and lower-body weightlifting	50 min	21 sets
	Rest	10 min	—
	Run	3.2 km	Includes interval runs
Tuesday	Upper- and lower-body weightlifting	50 min	21 sets
	Rest	10 min	—
	Varied drills	0–30 min	Simulated occupational tasks
Wednesday	Backpack	8 km at ≥6.4 km·h^{-1}	Load weight based on previous performance
Thursday	Upper- and lower-body weightlifting	50 min	21 sets
	Rest	10 min	—
	Varied drills	0–30 min	Simulated occupational tasks
Friday	Upper- and lower-body weightlifting	50 min	21 sets
	Rest	10 min	—
	Run	3.2 km	Includes interval runs

Table 2. Initial workout schedule: weeks 1–19.*

Monday and Thursday				Tuesday and Friday			
Sequence	Exercise	Range of weight lifted (kg)	Number of repetitions	Sequence	Exercise	Range of weight lifted (kg)	Number of repetitions
1	Squat	20.5–111.4	4–10	1	Underhand medicine ball toss	4.5–7.3	10
2	Bench press	18.2–56.8	4–10	2	Wide-grip barbell press	18.2–31.8	4–10
	Repeat exercises 1 and 2, 6 times				Repeat exercises 1 and 2, 3 times		
3	Back hyperextension	0–11.4	—	3	Underhand medicine ball toss	4.5–7.3	10
4	Medium grip barbell press	13.6–38.6	—	4	Wide-grip barbell pull down	22.7–54.5	6–10
5	Row with elbows high	18.2–45.5	—		Repeat exercises 3 and 4, 3 times		
	Repeat exercises 3–5, 3 times						
				5	Sit-up		
				6	Leg curl	13.6–45.5	—
				7	Row with elbows high	18.2–45.5	—
					Repeat exercises 5–7, 3 times		

* Weight training intensity peaked at week 14. Hill running, interval training with and without loads, lifting and carrying, and jumping with loads were added after week 8.

ing-related overuse, traumatic, or wound resulting in a medical evaluation. Overuse injuries were defined as musculoskeletal injuries assumed to be caused by repetitive microtrauma associated with training. Traumatic injuries were acute injuries associated with a single event, like falling with a backpack. Wound injuries were blisters associated with repetitive microtrauma to the skin occurring during certain activities such as hiking. A lost training day was an injury-related 24-hour period of medical restriction from physical activities. If an injured woman participated in an alternative physical activity (e.g., stationary bike), this was recorded as lost training time.

Statistical Analyses

The descriptive analyses were performed on all women who participated in the 24-week training program. All injury data were entered into an EXCEL spread

Table 3. Workout schedule: weeks 20–24.

	Two day per week workout		
Sequence	Exercise	Range of weight lifted (kg)	Repetitions
1	Medicine ball sit-up	4.5	20
2	Step-up*	0–11.4	20
3	Pull-up exercises	†	10
	Repeat exercises 1–3, 3 times		
4	Incline bench press	15.9–52.3	4–10
5	Lunge	0–20.5	—
	Repeat exercises 4 and 5, 3 times		
6	Row with elbows high	—	—
7	Back hyperextension	0	10
	Repeat exercises 6 and 7, 3 times		
8	Side-to-side jumps*	0–11.4	20
9	Dumbbell clean and jerk	4.5–15.9	—
10	Medicine ball chest pass	4.5	20
	Repeat exercises 8–10, 3 times		
11	Military press, med grip	11.4–34.1	4–10
12	Row with elbows low	18.2–45.5	—
	Repeat exercises 11 and 12, 3 times		
13	Leg press/calf push	31.8–177.3	—
14	Upright row	9.1–25	—
	Repeat exercises 13 and 14, 3 times		
15	Dips	†	—
16	Lateral dumbbell raise	2.3–6.8	10
17	High arm curl	9.1–25	10
	Repeat exercises 15–17, 3 times		

* Step-ups and Side-to-side jumps are done without weights and then with weights up to 11.4 kg.

† Pull-ups and dips are done with and without assistance: using body weight and decreasing to 0 using a weight-start machine that pushed upward on the feet.

sheet and up-loaded for analysis. Univariate analyses were conducted using Epi-Info version 6.0 (Centers for Disease Control, Atlanta, GA).

The total number of initial clinic visits, follow-up visits, and lost training days were tallied for injuries. The cumulative incidence (percentage) of individuals with 1 or more new injuries was calculated by dividing the number of women with 1 or more injuries by the total number of soldiers in the training study. Rate of injury (per 1,000 hours of exposure) associated with lost training days was calculated by dividing the number of injuries associated with at least 1 day of lost training time by the number of women in the study and by the hours of training exposure, and then multiplying by 1,000.

Associations between potential risk factors and incidence of injuries were examined using χ^2 statistics. Partitioned χ^2 were used against a reference group (e.g., group of women with the lowest injury risk) in cases where significant differences were found in variables having more than 1 level. Continuous variables (age, body stature, prestudy fitness) were separated into equal-sized groups with numeric cut points based on the group distribution for that variable.

Logistical regression (using the statistical software package) was used to examine the interrelationships among potential risk factors and injuries.

Results

The average age (mean ± *SD*) of the participants was 27.5 ± 3.9 years. (range: 20.0–37.0 years). Table 4 shows mean pre- and posttraining body measurements. Previous data has shown that women in the Army between the ages of 27 and 31 years have a mean height of 163.7 ± 8.4 cm and a mean body mass of 61.6 ± 7.8 kg (6). Thus the women in this study were, on the average, heavier than reported in Army normative data tables for women soldiers in this age range. Significant changes in body composition were noted pre- to posttraining. Mean muscle mass increased by 1.3 kg, and body fat decreased by 3.8% (3).

Demographic Questionnaire Data

A majority of the women had at least 1 year of college education, and their jobs were primarily nonphysical, such as teaching and secretarial work. Most of the women had participated in competitive high school sports and routinely participated in either aerobic exercise programs or combined strength and aerobic exercise programs at least twice weekly prior to the

Table 4. Pre- and posttraining body measurements of study participants (Mean ± *SD*).*

Characteristic	*n*	Pre	*n*	Post	*p*-value
Height (cm)	45	163.3 ± 6.5	32	—	—
Body mass (kg)	45	69.5 ± 12.5	32	68.1 ± 11.2	<0.05
DEXA % fat	45	35.6 ± 8.8	32	31.8 ± 7.7	<0.001
Lean body mass (kg)	45	41.3 ± 4.8	32	42.6 ± 4.2	<0.001

* Harman et al. (3).

Table 5. Pre- and posttraining test measurements (Mean ± *SD*).*

Tests	Women				
	n	Pre	*n*	Post	Mean percent change
52-in. box lift (lb)	45	88.2 ± 18.20	32	117.50 ± 21.20	+33
30-in. box lift (lb)	45	130.6 ± 26.90	32	175.40 ± 25.00	+34
30–60-in. box lift (lb)	45	58.6 ± 13.50	32	87.30 ± 17.10	+49
40-lb, 52-in. box lift (repetitions)	45	104.4 ± 20.80	32	139.60 ± 18.30	+34
40-lb, 52-in. box lift, 25-ft carry (repetitions)	45	52.2 ± 7.00	32	61.70 ± 5.90	+18
Vertical jump (in.)	45	12.5 ± 2.90	32	14.80 ± 3.00	+18
Standing long jump (ft)	45	4.93 ± 0.79	32	5.73 ± 0.88	+16
100-lb barbell squat (repetitions)	45	15.8 ± 13.60	32	62.10 ± 29.40	+293
$\dot{V}O_2max$ $ml \cdot kg^{-1} \cdot min^{-1}$	45	40.9 ± 5.30	32	46.50 ± 5.50	+14
2-mile, 110-lb trailer tow (miles per h)	45	4.33 ± 0.56	32	5.01 ± 0.56	+16
2-mile, 75-lb pack hike (miles per h)	45	3.33 ± 0.37	32	4.44 ± 0.69	+33

* Harman et al (3).

study. Of the 45 participants, 37.0% were smokers and 60.0% reported a current or past history of consumption of at least 1 alcoholic drink at least once per week.

For reproductive histories, 9 of the 45 women reported a past history of childbearing. Ten individuals took oral contraceptives before and during the training program. Three women reported menstrual irregularities prior to training that continued throughout the training. Two individuals developed irregular menstrual cycles during the training (not pregnant).

Performance Data

Table 5 shows a comparison between pre- and posttraining performance measurements of the 45 women study participants, of which 32 completed the training (3). There was a mean 34% change of improvement in maximum box weight lifted to a height of 30 in. and a mean 33% change in maximum box weight lifted to a height of 52 in. Also, there was a mean 49% change of improvement in maximum box weight lifted from 30 in. to 60 in. The box lift tests involved an individual lifting her maximum box weight from the floor to truck-bed height (52 in.), from the floor to table height (30 in.), and from table height (30 in.) to 60 in. Vertical jump increased by 18% and long jump by 16% among the women participants. The average number of squat repetitions with a 100-lb barbell increased fourfold. Backpack marching speed increased by 1.11 $miles \cdot h^{-1}$.

Injuries

Figure 1 shows the frequency of injuries in 4-week increments throughout the 24-week program. The frequency of injuries peaked at week 12 of training when both the running intensity and amount of weight lifted were approaching a peak in week 14. The injury incidence (number of women with one or more injuries) was 48.9% (22 of 45). Table 6 shows the types of injuries and associated days lost from training. There were a total of 24 injuries reported for 22 injured women. Overuse-type injuries were the most common injuries reported (79%). Patellar tendonitis, hip bursitis, calf strain, and knee meniscal tear injuries accounted for 64.0% of the total clinic visits.

Of the 22 injured women in the study, 18 suffered injuries, resulting in a total of 69 lost training days. There were a total of 23 injuries associated with at least 1 day of lost training time. The rate of injury associated with lost training time was 2.8 injuries per 1,000 hours

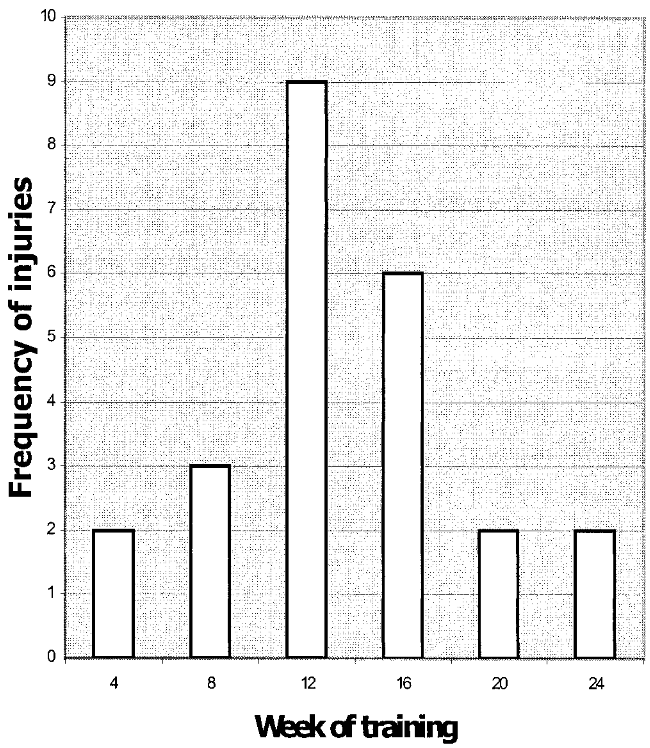

Figure 1. Frequency of injuries per 4-week training period.

Table 6. Training injuries and associated days lost.

Injury	Number of injuries†	Total clinic visits* Number of clinic visits	Percent	Number of days lost
Overuse	19	81	91.0	64
Low back strain	3	4	4.5	11
Patellar tendonitis	3	13	14.6	9
Hip bursitis	2	18	20.2	2
Cervical strain	2	4	4.5	7
Calf strain	2	13	14.6	1
Knee meniscal tear	1	13	14.6	11
Sciatica	1	6	6.7	7
Knee bursitis	1	3	3.4	6
Knee ligament sprain	1	3	3.4	5
Foot metatarsal pain	1	1	1.1	0
Knee pain	1	1	1.1	3
I T band tendinitis	1	2	2.3	2
Traumatic	2	3	3.4	2
Ankle sprain	1	1	1.1	1
Head contusion	1	2	2.3	1
Wound	3	5	5.6	3
Foot blister	3	5	5.6	3
Total	24	89	100.0	69

* Total clinic visits include initial and follow-up visits.
† Individuals may have more than 1 injury.

of training exposure. Low back strain, knee meniscal tear, and patellar tendinitis injuries were associated with the greatest number of training days lost.

Table 7 shows training injuries and associated days lost by body part. Most injuries involved the lower body. Injuries involving the knee, hip, and calf resulted in 74.2% of the total clinic visits. Injuries involving the knee and lower back accounted for the greatest number of days lost from training.

Table 8 presents injuries and days lost by types of training activities. Injuries resulting from weightlifting and backpack hiking accounted for 61.8% of the total clinic visits. Weightlifting-related injuries resulted in the greatest number of days lost from training.

χ^2 and logistic regression analysis showed no associations between injuries and age, body stature, pretest fitness, tobacco/alcohol use, exercise and competitive sports history, educational background, occupational history, or menstrual/childbearing history.

Discussion

The periodized strength and running training program in this study resulted in significant performance gains. Comparing the women's posttraining measurements with men Army samples from other studies (n = 388; 9, 12) reveals some interesting findings. The women's final average maximum box weight lifted to 52 in. was 81% of the average maximum box weight lifted to 52 in. by the Army men (117 vs. 144 lb). The final average number of squat repetitions with a 100-lb barbell was 97% of the average repetitions reported in the other studies (62 vs. 64 repetitions). Also, the final backpack marching speed was 80% of the speed measured in the Army men samples (4 vs. 5 miles·h^{-1}).

The periodized model in this study resulted in a relatively low injury rate. There were 24 injuries reported for 45 participants, leading to only 2 women dropping out because of training-related injuries. Knapik et al. (7) conducted a 14-week, nonperiodized running and resistance training program in 21 women soldiers that resulted in only 2 women leaving the pro-

Table 7. Training injuries and days lost by body part.

Location	Number of injuries†	Total clinic visits* Number of clinic visits	Percent	Number of days lost
Upper body	3	6	6.7	8
Neck	2	4	4.5	7
Head	1	2	2.2	1
Lower body	21	83	93.3	61
Knee	7	33	37.1	34
Lower back	4	10	11.2	18
Foot	4	6	6.7	3
Hip	3	20	22.5	4
Calf	2	13	14.6	1
Ankle	1	1	1.1	1
Total	24	89	100.0	69

* Total clinic visits include initial and follow-up visits.
† Individuals may have more than 1 injury.

Table 8. Injuries and days lost by training activity.

Training activity	Number of injuries†	Total clinic visits* Number of clinic visits	Percent	Number of days lost
Strength training	7	31	34.8	40
Backpack hiking	6	24	27.0	7
Running	4	18	20.2	8
Unknown	7	16	18.0	14
Total	24	89	100.0	69

* Total clinic visits include initial and follow-up visits.
† Individuals may have more than 1 injury.

gram because of training-related injuries. However, the performance gains in this nonperiodized program were not as great as reported in the present periodized program.

The rate of injuries associated with lost training time in the present study was similar to Army basic combat training for women soldiers (2.8 vs. 2.8 per 1,000 hours of training exposure; 15). However, the performance gains in strength and endurance in the present periodized training model appear to be more significant than seen in basic training. The performance gains may be important for training for ''very heavy'' Army job requirements.

The rate of injury associated with lost training days for the present study was higher than that reported by Clark et al. (1) for women's collegiate sports involving strength, endurance, and speed training such as basketball (2.8 vs. 2.5 per 1,000 hours of training exposure) and track and field activities (2.8 vs. 2.2 per 1,000 hours of training exposure). However, the injury rates reported by Clark et al. (1) only represented ''significant'' injuries that were associated with at least 1 week of lost training time. The injury rate in the present study reflected injuries associated with lost training time of 1 day or more. Perhaps the differences in the operational definitions between the 2 studies may account for the higher injury rate reported in the present study.

It is interesting that the frequency of injuries peaked in week 12 when the physical load was approaching a peak in week 14, followed by a decrease in injuries with reductions in running mileage and weight lifted. Perhaps the peak frequency of injury (4) could have been reduced with progressively slower increases in running mileage and weights lifted. However, the performance gains may have been less and possibly delayed. It is also important to note that injury frequency did not peak again when the weight lifted and running mileage were increased in the last few weeks of the training program. Perhaps the women were already conditioned at this point and less vulnerable to injury. Also, the less sturdy women may have dropped out by week 12.

The study showed that a majority of the injuries were associated with either weight training or backpack hiking. These injuries were primarily overuse-type injuries. Generally it is difficult to determine an inciting event that caused this type of injury. Also, the women in this study were involved in multiple training events. However, it is possible that an overuse injury could occur during a single event (i.e., weightlifting) if the participant was not conditioned despite using proper lifting technique. Therefore, we were basing our results on data that were collected at the training site. The authors assumed that the injury occurred as a result of the participant not being conditioned at that point.

In conclusion, the periodized training model requires trainers that are experienced and well trained, which may be a limitation of this training program. However, there are several benefits of utilizing a periodized training model if a trained staff is available. Periodized training may result in greater strength and performance gains than a majority of nonperiodized strength and running workouts. Also, the model allows for scheduled changes in the routine that helps maintain motivation. It is a well-balanced strength and aerobic program that progressively increases in intensity in a step-wise fashion and results in a relatively low injury rate.

Practical Applications

This study has shown that a well-organized periodized strength and aerobic training program can result in significant performance gains with a relatively low injury rate. The rate of injury associated with lost training days in this training program was no higher than reported for women in basic training (15). Perhaps a periodized strength and aerobic program could be incorporated in Army physical training programs for military occupational specialties involving heavy lifting tasks and endurance activities. Also, women athletes involved in sports requiring speed, endurance, and strength may benefit from this type of combined program.

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