

Commentary

Supramaximal Eccentric Training for Alpine Ski Racing—Strength Training with the Lifter

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Featured Application: The Intelligent Motion Lifter is a new mechatronic strength training device that allows safe and effective strength training with supramaximal loads.

Abstract: Eccentric muscular work plays a large role in alpine ski racing. Training with supramaximal eccentric loads (SME) is highly effective to improve eccentric strength but potentially dangerous. Most SME training devices do not allow the athlete to move a barbell freely as they would when performing conventional barbell training. The Intelligent Motion Lifter (IML) allows for safe SME training with a free barbell and no spotters. The IML can be used for free barbell training; a spotter for normal training, eccentric only, concentric only, and squat jumps. It is also a training and testing device for isokinetic and isometric exercise. This commentary addresses the necessity of eccentric training for elite alpine ski racers, the development of the IML and its use in training.

Keywords: eccentric; alpine ski racing; strength training; supramaximal loads; athlete safety

1. Eccentric Exercise in Alpine Ski Racing

Scientific analysis of world class Swedish alpine ski racers in the 1990s [1,2] showed that eccentric muscular work predominated over concentric work in the disciplines of slalom, giant slalom and super G. More current work with elite Swiss racers corroborated this [3–5], with Vogt and Hoppeler stating that alpine skiing is “the only sport activity dominated by eccentric muscle activity” [5].

The introduction of carving (greater side-cut) skis in World Cup ski racing in 1999 changed ski turns [6]. Ferguson [7] concluded that ski racing is characterized by isometric and eccentric muscular actions. New studies with Austrian [8] and French [9] elite ski racers have indicated that a “quasi-isometric” phase exists in ski racing and that this phase of the ski turn has been overlooked but must be considered.

There is still an incomplete understanding of what is happening during a high-speed ski turn. More research is needed for a full understanding of the metabolic and muscular functional demands of ski racing [10], and there is “a lack of functional and biomechanical understanding of the performance relevant parameters” in ski racing [11].

The dominance of eccentric muscular actions in ski racing can be debated, but eccentric muscular control is important in the sport. Gravity propels the ski racer down the hill [12,13] and the racer must efficiently use potential energy to maintain speed on a racecourse. A kinematic analysis of a World Cup slalom race [13] found that faster racers better controlled the dissipation of potential energy and could more effectively reduce ground reaction forces compared to slower performers. Reid et al. [14] also demonstrated that more energy is dissipated in skidded turns than in carved turns with Norwegian national team ski racers.

We believe that high levels of eccentric strength are necessary to control the dissipation of energy during a skiing turn. Higher strength levels allow the ski racer to work with less relative strength, which may lead to more control in turns (less energy dissipation) and less fatigue during races.

Swiss sport scientists working with the Swiss ski team [3] have built an “Eccentric-Trainer”. This special cycle ergometer forces the athlete to eccentrically “brake” the machine to achieve the selected power output and cadence. They found that the ability of the racer to precisely control the eccentric work correlated with International Ski Federation points, which is the system of grading ski racers’ racing success. The better control of the eccentric work, the better the ski racer.

The effectiveness of eccentric training in improving maximal strength has been known for some time [15]. The most effective uses of eccentric training seem to be high speed eccentric work and heavy eccentric loading [16]. Many athletes employ supramaximal eccentric training (SME) to improve maximal strength, which may improve performance. World class powerlifters can use 105–110% of their one repetition maximum and lower-level athletes can use 120–130% for SME training [17].

The Norwegian alpine ski team trained with SME squats regularly in the 1990s [17]. A minimum requirement for the squat (hip joint at least same level or lower than knee joint) was 2.5 times bodyweight for the men’s Europe and World Cup teams. They also tested for maximal eccentric force with a negative (from top to bottom with control) squat.

Elite sport training centers have developed their own SME squat machines in Austria [18], Norway [17] and Sweden [19], and as mentioned above, the Swiss have designed an eccentric cycle ergometer for ski racers [3]. There are anecdotal references of athletes using supramaximal squats to prepare for ski racing. Bode Miller, a very successful American ski racer, built his own training device in order to perform eccentric squats. We have had personal communications with Canadian and American coaches and know that supramaximal eccentric squats are used in the training of alpine ski racers in other nations. In reviews of the training of alpine ski racers, eccentric training is recommended [20,21].

In a recent review of nine different eccentric training devices [22], the Intelligent Motion Lifter© (IML), from Intelligent Motion GmbH (Wartberg an der Krems, Austria) is the only device which allowed the athlete to move the barbell freely in all planes as they would when performing conventional barbell training.

Free weights, when compared to machines, allow movement in multiple planes, require balance, and mimic natural acceleration and velocity patterns, resulting in a greater transfer of training effect [23]. Electromyographic (EMG) activity is greater when training with free weights, perhaps due to the action of stabilizing muscle groups [24]. A free barbell bench press elicited more muscle activity than a machine bench press [24], and free weight squats showed 43% higher EMG activity than Smith machine squats [25].

Weight releasers are a cost-effective method for barbell SME training, and their use has been documented in scientific studies [26–28]. However, this system is strenuous for coaches or helpers and the athlete must have very good lifting technique to ensure that the two releasers hit the floor simultaneously.

Patterson and Raschner [29] reported a case study with an Austrian world champion ski racer utilizing the Intelligent Motion Lifter© (IML), from Intelligent Motion GmbH (Wartberg an der Krems, Austria) for SME training.

Coaches and athletes must be aware that SME barbell squat training is extremely strenuous and potentially dangerous. Spotters must be properly trained to safely spot the squatter, and SME training requires multiple spotters. The IML makes safe SME barbell training possible without spotters.

2. Development of the IML

The initial goal was to develop a device to allow safe SME training. A high priority was that the barbell would have 100% freedom to move in all three planes during SME loading, so that the normal demands of free weight training would be met (see Figure 1).



Figure 1. The Intelligent Motion Lifter© (IML) prototype in 2010. From left to right: bench press, bench pull and squat.

A needs analysis concluded that the following conditions must be met:

- The device will safely and quickly stop the bar if the athlete “fails” during a lift.
- The barbell will move freely (in all planes) during the eccentric portion of lift.
- There will be no external adjustments to the barbell load during a multiple repetition set.
- Automated assistance will be provided to safely return the barbell to the starting position of the eccentric phase (no concentric phase for the athlete).
- The range of motion (top and bottom of lift) can be adjusted for each athlete.
- The range of motion for all lifts performed by an athlete will be saved by the device.
- The device will provide training data which can be exported for training documentation.
- The machine can be used as a spotting device during normal lifts.
- The machine will have dimensions similar to a normal power rack.
- The machine cannot be used without a coach or training partner to operate the device.

The Lifter was originally conceived for SME training, but further developments allow the device to be used for concentric-only training, isometric training, and testing, and as a spotter for normal barbell lifts and jumping. The additional functions that were added to later versions of the Lifter included:

- Automated assistance will be provided to safely return the barbell to the starting position of the concentric phase (no eccentric phase for the athlete).
- The arms will move fast enough that an athlete can perform a loaded squat jump or countermovement jump and the arms will catch the barbell at the top of the jump.
- Isokinetic movements can be performed with a bar attached to the arms in both concentric and eccentric movements. The force applied by the athlete on the arms will be measured and recorded.
- Isometric testing and training can be performed with a bar coupled to the arms. The force applied to the bar by the athlete will be measured and recorded.
- The velocities of the concentric and eccentric phases of the isokinetic movements can be independent of each other; one phase can be faster than the other.

These conditions were taken into consideration when developing and constructing the IML. The IML is a safe automated mechatronic SME device which requires one operator and no external load adjustments during training. A prototype of this training device was introduced at the International Conference on Strength Training 2010 [30].

3. Description of the IML

The IML is essentially two lifting systems utilizing mechatronic technology. Each system has a lifting arm and consists of a column with a drive spindle, guide rails and a synchronized servomotor. The two drives can be virtually coupled via the software and the arms can operate independently of each other. The system is controlled by a real-time capable central processing unit (CPU).

The arms move with the barbell as it is lowered or raised without contacting the barbell. The displacement and speed of the barbell is tracked by two draw-wire encoders attached to the barbell with lightweight plastic plates, which slide onto the barbell similar to weight plates (see Figure 2).



Figure 2. The draw-wire and plate of the draw-wire encoder.

The height difference between the two arms is automatically limited to 100 mm. If the difference exceeds 100 mm, the machine will automatically move one of the arms to stay within 100 mm. The arms can work independently so that the athlete must balance the bar as in a normal free barbell squat. The arms can also be programmed to work together, so that the barbell still moves freely, but the athlete does not have to concentrate on keeping the barbell level. The arms can be programmed to follow the barbell at a distance of 12.5 to 100 mm, allowing a tolerance limit for keeping the barbell level.

A free barbell can be raised and lowered to heights of 1850 mm and 550 mm, respectively, and the simulation bar can be raised and lowered to heights of 1750 mm and 450 mm, respectively. The maximum barbell load is 400 kg and the maximum simulated load is 250 kg.

The maximum velocity of the arms is 2000 mm/s and the minimum velocity is 10 mm/s. The maximum acceleration of the arms (full load or empty) is 4000 mm/s².

The entire machine is controlled by a mobile handheld control unit, which has a touchscreen display, an emergency stop switch, and an override switch. This unit is attached by cable to the IML. There is also a screen on the IML for athlete instructions.

4. Safety Standards of the IML

Various safety functions ensure maximum safety during training with the IML. The IML has two CPUs which monitor the programmed safety elements. These are:

- All emergency stop switches,
- The speed of the barbell,
- The displacement of the barbell, and
- The bottom movement limits of the exercise.

There are four emergency switches. Two are on the sides of the IML, one is on the handheld control unit and one is mounted on the front wall facing the athlete at foot height (see Figure 3). If an emergency switch is activated, the arms will stop. The programmed movement range and speed of the barbell is monitored by the safety CPUs. In order to actively move to the lowest positions in training, the override switch on the handheld unit must be pressed during the entire exercise. If the override switch is not pressed, the arms will automatically stop.



Figure 3. The present IML model: squat top position and squat bottom position.

All safety elements, including the safety CPUs, have the highest safety level in control technology and automation available at the time of manufacture: safety integrity level (SIL) 3. A discussion of how safety standards and risk assessment systems for manufacturers and approval agencies are developed has been presented by Stavrianidis and Bhimavarapu [31].

An additional safety feature has been developed. In the bench press, the barbell or the coupled bar is lowered to the chest and the athlete may fear that the bar will crush them. A mechanical safety pin system can be placed onto the floor supports and this will brake the arms so that the coupled bar or barbell will not crush the athlete. The safety CPUs prevent this, but the safety pin system assures the athlete that he or she is safe (see Figure 4).



Figure 4. The mechanical safety pin system.

5. Training and Testing with the IML

5.1. Training Mode

5.1.1. Training with a Free Barbell

First, the upper and lower limits and lift off position of the lift are set for the athlete. The number of sets and repetitions can be prescribed. The coach can operate the machine manually, or program the number of sets, repetitions, and rest periods between repetitions and sets. The velocity and the acceleration of the arms can be programmed, dictating the speed of movement and the “hardness” or “softness” of the change of direction between the raising and lowering of the arms. There is also an “aggressiveness” setting, which controls how quickly the arms follow the movement of the barbell.

5.1.2. Spotter Mode

The arms are positioned under the barbell (but without contact) and follow the path of the bar at a predetermined distance (12.5–100 mm). The athlete is able to train normally with no help from the machine. When the set is done, the athlete can rack the bar onto the arms (see Figure 3).

5.1.3. Eccentric Only Mode

The athlete loads the barbell onto the back from the lift off position and lowers the barbell under control to the lower limit. The arms lift the barbell back to the lift-off or upper limit. The rest at the top can be programmed or determined manually by the coach.

5.1.4. Concentric Only Mode

The athlete starts with the barbell at the lower limit and lifts the barbell to the upper limit. The arms lower the barbell back to the lower limit. The rest at the bottom can be programmed or determined manually by the coach.

5.1.5. Throw or Jump Mode

The barbell is caught by the device in loaded jumps or bench press throws (or other dynamic exercises). For a jump, after lift-off, the athlete lowers into a controlled countermovement and when the lower limit is reached, a beep signals the athletes that he/she can jump. The arms are then “triggered”

and once the barbell starts to move upwards the arms will follow the barbell up (velocity of arms is 2000 m/s) and catch the bar at a height of 1850 mm.

5.2. Training with the Simulation Bar

As in the free barbell modes, the upper and lower limits of the lift are set with the athlete. The number of sets and repetitions can be set. The coach can operate the machine manually, or program the number of sets, repetitions, and rest periods between repetitions and sets. The arms can be locked in place or allowed to move in the horizontal plane up to 450 mm (see Figure 5). Force sensors in the arms allow the force on the simulation bar applied by the athlete to be precisely recorded during training. The force measurements evaluate the exercise and can regulate simulated loads.

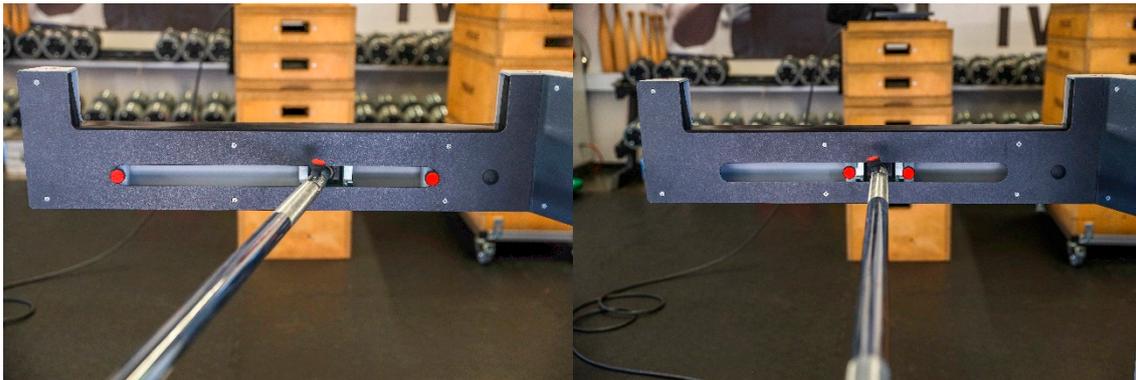


Figure 5. The simulation bar free (left) and locked (right).

5.2.1. Isokinetic Mode

The arms move the simulation bar at a pre-selected constant velocity (50–400 mm per second) between the set upper and lower limits. The eccentric and concentric phases can be run at different velocities. This is isokinetic training. This can also be used as a roller simulator for skiers and snowboarders. A board is attached to the device and that athlete absorbs the rolls as the arms move up and down.

5.2.2. Simulated Load Mode

The simulated load is set in kilograms and can be configured for both the concentric and the eccentric movement direction and can be constant, increasing or decreasing. For example: Training exercise: squat, eccentric: 220 → 180 kg; concentric: 150 → 180 kg. At the start of the motion (upper motion limit), 220 kg is simulated. As the barbell continues downwards, the weight is reduced to a training load of 180 kg at the lower motion limit. Once the lower limit is reached, the controls switch to a training load of 150 kg. As the barbell moves upward, the load is linearly increased until 180 kg is reached at the upper limit. When the upper limit is reached, the controls again switch to the setting for the eccentric movement.

5.3. Measuring Strength with the Simulation Bar

5.3.1. Isokinetic Measurement

The simulation bar is attached to the arms. The arms move up and down between the defined upper and lower limits at a constant speed. The velocity and the acceleration set by the coach define the speed of the bar and the hardness of the change of direction. The force applied to the bar is measured.

5.3.2. Isometric Measurement

For isometric measurement, the position of the simulation bar is set manually, and the arms hold the configured position. The force applied to the bar is measured statically.

6. A Case Study—Training with the IML

6.1. Methods

A 30-year-old Austrian female ski racer (winner of multiple Olympic and world championship medals) trained with the IML. The general physical preparation (GPP) of this athlete was from May to October 2011 (see Table 1). Height and weight during the GPP were 166 cm and 65.0 kg, respectively. As an athlete training at the Olympic Training Center, Department of Sport Science, University of Innsbruck, she was given verbal and written descriptions of training and informed of the risks of associated with participation in elite sport and training. She signed an athlete agreement, which included an informed consent for training. She also underwent a medical check up to ensure that there are no contraindications to participating in her sport or training at the center. The athlete agreement (#01/2011) was approved in 2011 by the institutional review committee of the Department of Sport Science of the University of Innsbruck and the board for ethical questions of the University of Innsbruck.

The SME training phase was performed with squats, over a four-week period, with two SME sessions per week. At the start of this phase, a one-repetition maximum (1RM) test was performed. The depth of the squat was similar to that of a powerlifting squat. At the bottom of the squat, the top surface of the legs at the hip joint was lower than the top of the knees.

Most squat sessions had at least five eccentric only loading (EOL) sets with 2–4 repetitions, and 4–6 heavy sets (1–3 repetitions) of normal squats (see Table 2). The athlete would lower the bar to a 5 s count, and the IML would return the bar to the starting position. EOL sets were alternated with normal squat sets, with a rest between 3–6 min. A maximum total of 12 heavy sets of squats were performed. Training loads were progressively increased. Training volume was calculated, but only for loads of 100 kg (89% of original 1RM) or more. Leg training sessions also included lunges, Romanian deadlifts, and hamstring curls (2–3 sets and 6–8 repetitions). The last SME workout was 15 July 2011. During a five-week block in July and August, the focus was on ski training in Switzerland and New Zealand. Leg strength maintenance in this block included five leg training sessions, with three sessions utilizing one-legged squats (three sets of eight repetitions) and two sessions of normal squats (4–5 sets, up to 110 kg, 3–4 repetitions). The last week of August was a regeneration week. Strength training resumed on 6 September 2011 and a 1RM test was performed.

Table 1. Periodization of strength training in the general physical preparation (GPP). CON: conditioning camp, SKI: ski racing camp, RG: regeneration week.

MONTH	MAY	JUNE	JULY	AUGUST		SEPTEMBER	OCTOBER	
PHASE	GENERAL PREPARATION PERIOD			SPECIAL 1		REGENERATION - 1 WEEK	SPECIAL 2	SPECIAL 3
CAMPS		CON		SKI	OVERSEAS		SKI CAMPS EVERY WEEK, VARIED LENGTHS	
WEEKS IN CYCLE	2	5	4	2	3		4	3
STRENGTH	STABILITY	MAXIMAL	SME	MAINTAIN			POWER, MAINTAIN STRENGTH	
WORKOUTS (WO) SETS (S) REPS (R)	6 WO	10 WO 3-4 S, 3-5 R	7 WO 6-10 S, 2-4 R	2 WO 3-5 S, 3-8 R	2 WO 3-5 S, 3-8 R		HEAVY SQUAT: 2-5 S, 1-5 R; SPEEDSQUAT: 3-5 S, 5-8 R; JUMP: 2-5 S, 5-8 R	

Table 2. Squat training sessions in the supramaximal eccentric training (SME) phase. Dates are day and month. L = load in kilograms, R = repetitions, N = normal squats, EOL = eccentric only loading, 1L = one-legged squats. Training volume was calculated as training load × repetitions.

21.06	L	R	27.06	L	R	01.07	L	R	04.07	L	R	08.07	L	R	11.07	L	R	15.07			
N	40	15	N	40	15	N	40	15	N	40	6	N	60	6	N	40	10	N	40	6	
N	60	8	N	60	8	N	60	8	N	60	8	N	80	5	N	60	6	N	60	6	
EOL	60	3	EOL	80	3	N	80	5	N	80	5	EOL	110	4	N	80	5	N	80	5	
N	80	4	N	80	5	N	90	3	EOL	100	2	N	100	3	N	90	4	N	100	3	
EOL	80	3	EOL	90	3	EOL	100	2	N	100	3	EOL	110	4	N	100	3	EOL	110	3	
N	90	3	N	90	3	N	100	3	EOL	110	3	N	110	3	EOL	110	3	N	115	1	
EOL	100	3	EOL	100	3	EOL	110	2	N	100	3	EOL	120	33	N	110	3	EOL	120	3	
N	100	3	N	100	3	EOL	120	2	N 1 L	60	3	N	115	1	EOL	110	3	N	120	3	
N	105	3	EOL	110	3		115	1	EOL 1L	60	3	EOL	120	3	N	115	3	EOL	125	2	
N	110	3	EOL	120	4	EOL	125	2	N 1 L	60	3	N	117.5	1	EOL	120	3	N	120	3	
EOL	110	3	EOL	120	4		117.5	1	EOL 1L	75	3	EOL	122.5	3	N	115	3				
EOL	110	3				EOL	130	2	N 1 L	60	3	N	117.5	1	EOL	120	3				
N	115	1				N	120	1	EOL 1L	90	3	EOL	122.5	3	N	117.5	3				
						N	100	6	N 1 L	60	8	N	117.5	3	EOL	122.5	3				
									EOL 1L	90	3				N	120	3				
Workout Volume		Workout Volume		Workout Volume		Workout Volume		Workout Volume		Workout Volume		Workout Volume		Workout Volume		Workout Volume		Workout Volume		Workout Volume	
N	1060	N	300	N	1252.5	N	2640	N	1450	N	2385	N	1135								
EOL	960	EOL	1590	EOL	1170	EOL	2420	EOL	2335	EOL	1747.5	EOL	1060								
Total	1720	Total	1890	Total	2422.5	Total	5060	Total	3785	Total	4132.5	Total	2195								

6.2. Results

The subject's 115 kg 1RM squat increased to 127.5 kg (11%) from 21 June to 6 September.

7. Discussion

The athlete and coach considered the 1RM increase of 11% after a four-week block of EOL training followed by six weeks of maintenance training (five weeks skiing with strength maintenance and a regeneration week) a good training result. This increase may have been greater if she had performed a 1RM test one or two weeks after the four-week SME phase. This particular athlete had performed squats for over 15 years, but through most of her career had not trained "heavy" (1–3 maximal repetitions). Coaches and sport scientists concur that maximal absolute strength is best trained with heavy weights and low repetitions [32–34], and her strength gains were largely due to the increased intensity.

The increase in intensity and volume was gradual; this athlete was not familiar with heavy squats. The training volume on 4 July was so high because one-legged squats were performed. The athlete felt tired physically and psychologically and did not want to perform heavy squats, so single leg squats were used. However, as she progressed in the workout, she managed to do two sets of EOL single leg squats with 90 kg. The coach must understand the psychology of an athlete lifting heavy weights. The intensity is always relative to the athlete and their personal 1RM. The last SME session had the highest intensity with relatively low volume. The athlete squatted 5 kg more than her original 1RM for three repetitions. In subsequent seasons, this athlete was using as much as 165 kg for EOL squats.

The athlete felt that the increase in leg strength with SME training had a positive influence on her skiing. She also believed that the heavier loads used for squats improved her core stability. Some coaches maintain that heavy squats are one of the best core exercises.

One problem with comparing leg strength with ski racers is that there is no benchmark test. Austrian ski racers are tested with a multi-joint isokinetic leg press, and some nations use a single joint isokinetic leg extension machine; others test with squats. The problem with squats is that technique and squat depth varies from athlete to athlete, and nation to nation. One conditioning coach working with world class female racers insists that his athletes use deep squats similar to weightlifters, in which the hip joint is much deeper than the knee, often with the thighs on the calves. This is often referred to as a full depth squat. Others use a 90° knee angle as the bottom position, but many refer to this as a half squat, because of the minimal depth. In the present case study, the athlete used a depth similar to power lifters, with the top of the thigh below the top of the knee.

The following is mainly anecdotal evidence, but there is very little published work on squats with alpine ski racers. Beate Amdahl (now Amdahl Skorpen) was a Norwegian female powerlifter. At a body weight of 60 kg, she increased her 1RM from 180 kg to 210 kg during two years of eccentric training [17]. It should be clear that as a powerlifter, her competitive goal is to lift as much weight as possible for one repetition in competition. Pernilla Wiberg, a very successful Swedish female ski racer, had a best squat of 170 kg at a bodyweight of 67 kg. The depth of this squat was slightly above the depth of a powerlifting squat. Norwegian scientists have stated that all female Norwegian World Cup ski racers during the 1990s could squat 2.2 times their body weight once (powerlifting squat) [17]. The conditioning coach of one of the most successful male ski racers ever, Andre Kjetil Aamodt, maintained that Aamodt could squat 220 kg at 85 kg bodyweight, or 2.6 times his bodyweight.

Ski racers are using eccentric training to get stronger. A meta-analysis [35] determined that eccentric training is superior for strength and mass gains compared to concentric training, possibly due to the higher loading in eccentric work.

Enhanced strength gains from eccentric training are related to the neural demands of eccentric work. Eccentric movements require less motor unit recruitment than concentric [36], so the recruited motor units receive much more stimulation [37,38]. Nervous system control of eccentric actions is more complex than that of concentric work [36]; thus, neural adaptations to eccentric training are greater than those to concentric training [39].

The increased central nervous system load during SME leads to greater strength gains, but coaches and athletes must be wary of overtraining. In the present case study, SME twice a week elicited satisfactory strength gains without adverse effects. Norwegian sport scientists have recommended that athletes train with SME only once per week [17].

The 1080 Quantum Synchro by 1080 Motion is a new device that also allows SME with a barbell, but in a Smith machine, so the athlete does not have to control the path of the barbell. This is an unnatural way to perform barbell exercises and the athlete does not have to balance the barbell. The 1080 Quantum Synchro can be used with the following forms of resistance: isokinetic, normal mass, isotonic and ballistic. It appears that the eccentric barbell movements are isokinetic, but isokinetic movements do not exist in sport. It has a maximum eccentric resistance load of 325 kg; the IML can be loaded up to 400 kg. The 1080 Quantum Synchro can also be used with a cable system to allow sport-specific movements. This device looks very promising, and has been used in research [40].

The IML allows an athlete to train heavy with EOL squats with just one coach or partner to control the IML. Eccentric training is becoming more popular in GPP strength programs for alpine ski racers, and the authors believe that this trend will continue.

8. Conclusions

Properly planned strength training programs incorporating SME, which the IML supports, can improve maximal strength. The use of the IML as a SME training device for athletes who do not have an advanced level of strength is not advised. Athletes need to have the technical abilities and adequate strength to manage supramaximal loading. Athletes without high strength levels can utilize the device for other methods of training.

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