Eksentrisen flywheel-harjoittelun vaikutus hermolihasjärjestelmän suorituskykyyn – case jääkiekko

Science Meets Practice

TO 16.12.2021 klo 8.30-9.15

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Original Research

The Journal of Strength and Conditioning Research™

Effects of Flywheel vs. Traditional Resistance Training on Neuromuscular Performance of Elite Ice Hockey Players

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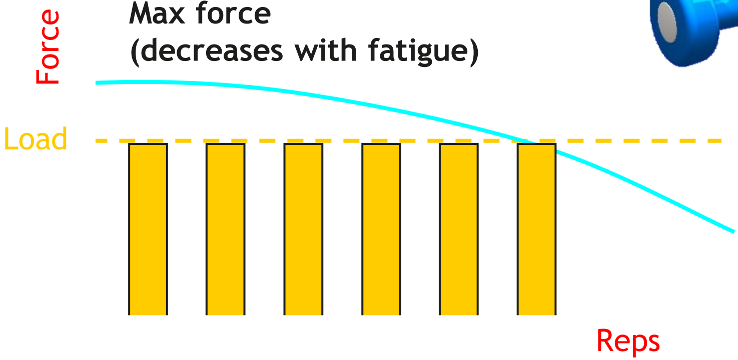
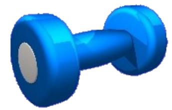
INTRODUCTION & HYPOTHESES

- The purpose of this study was to examine the effects of FW resistance training, using YoYo Technology machines, on strength, speed, change-of-direction ability, anaerobic performance, and power development of elite ice hockey players.
- Based on previous findings, it was hypothesized that FW training would result in greater gains in neuromuscular performance compared with traditional resistance training with free weights.
- Aim to have "real world" scenario

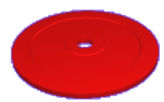
Flywheel vs. free weights

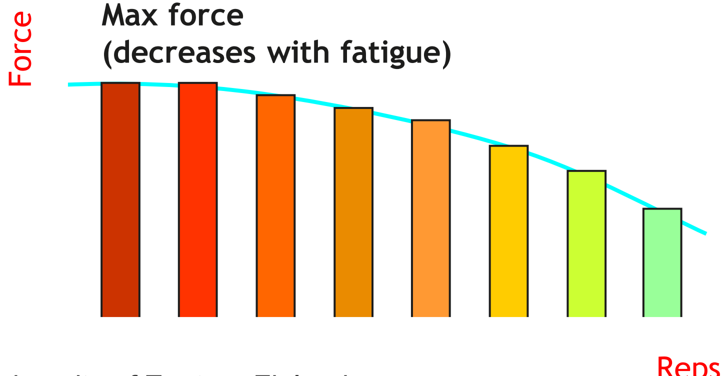




WEIGHTS

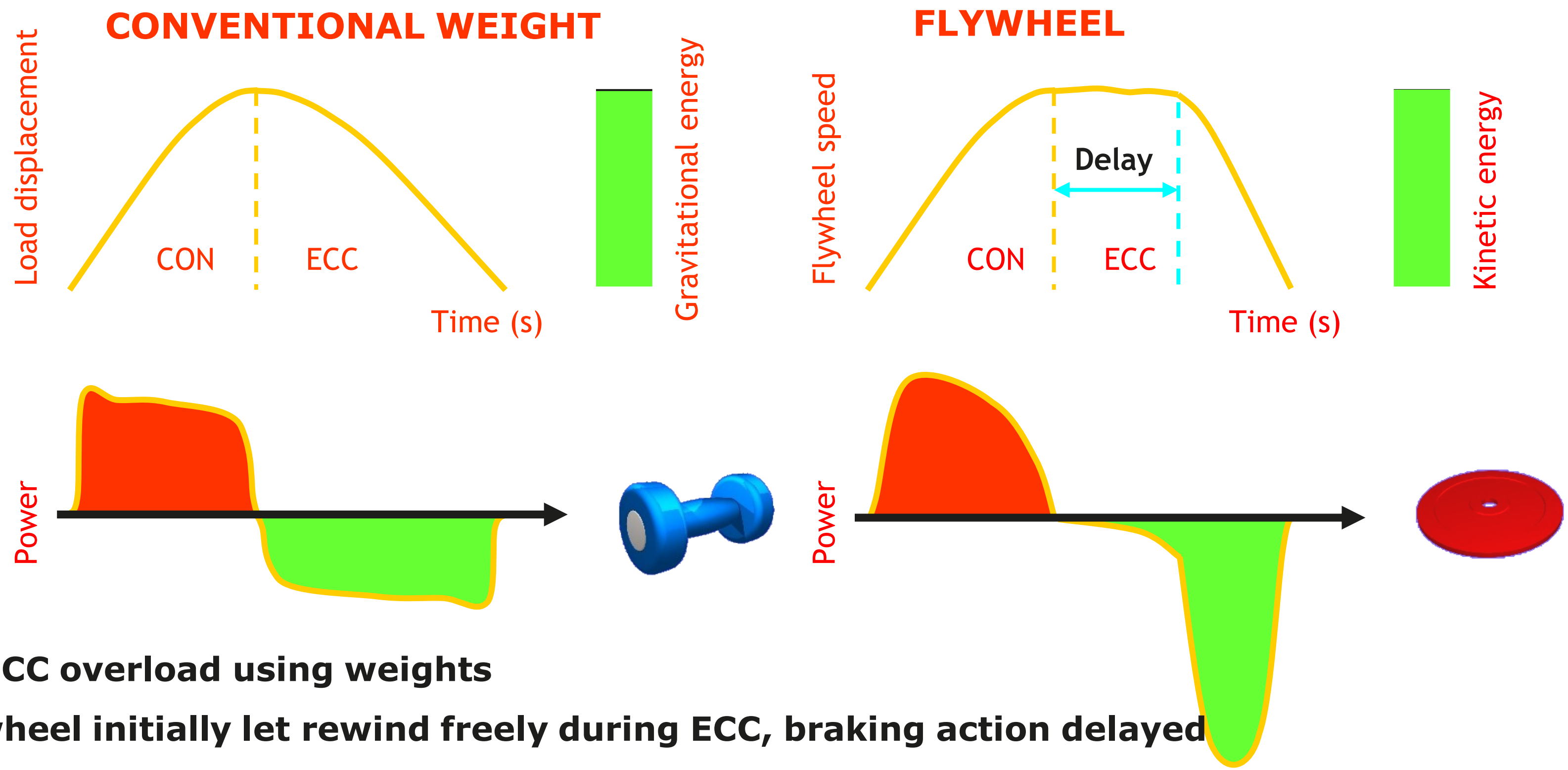
- Fixed load
- All reps at constant force
- All reps submaximal except last
- Set ends at failure to lift/pull
- Constant force thru entire ROM
  ➡ sticking point (requires cam)





FLYWHEEL

- Load adapts to force, no min force required to start/operate device
- All reps maximal thru ROM
- Less reps/set needed
- More work = ”training dose”
- Isoinertia, acceleration, deceleration



- No ECC overload using weights
- Flywheel initially let rewind freely during ECC, braking action delayed
- Power = Energy/time
- More delay, less time to dissipate energy ➡ ECC overload on power

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round the smallest pulley. At first we used a violoncello string but later we adopted a very thin steel band. The wheel is calibrated in the manner

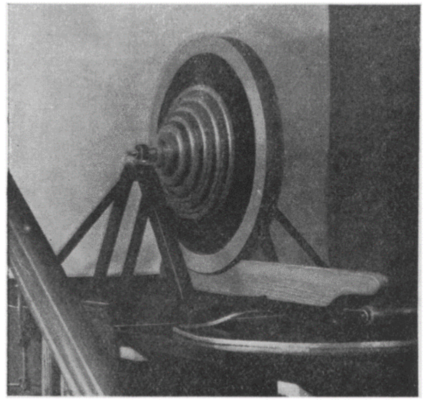
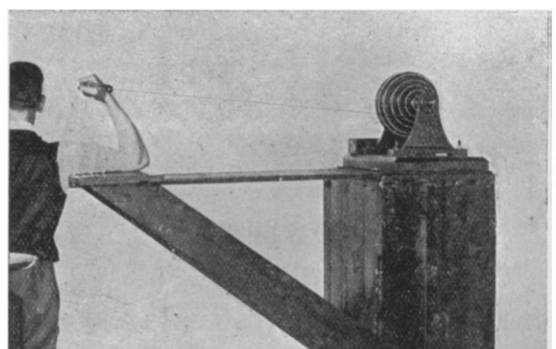
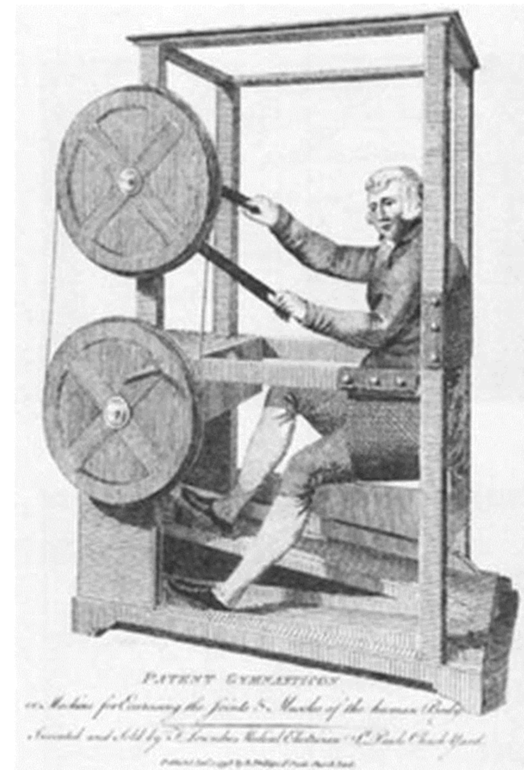
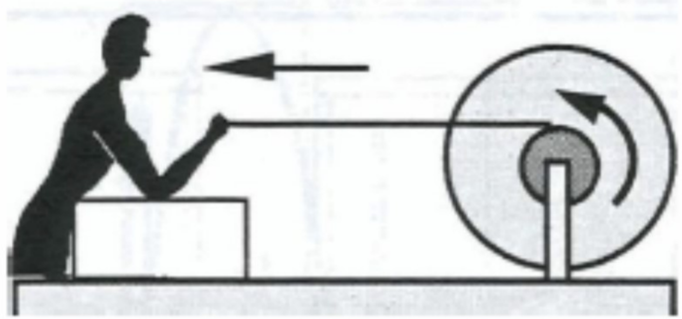


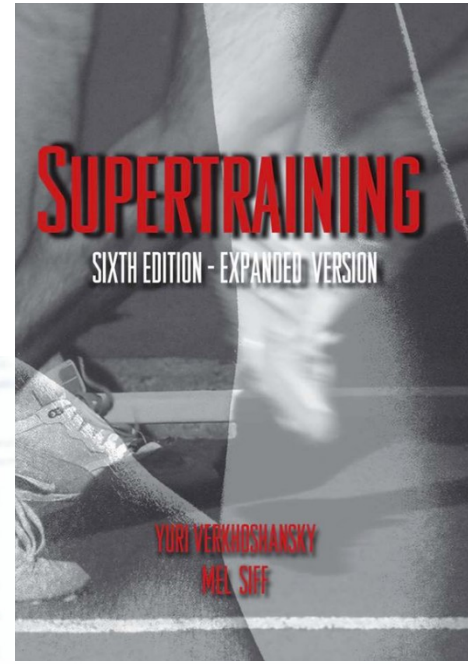
Fig. 1.

A.W.Hill (1920) ”An instrument for recording the maximum work in a muscular contraction”.







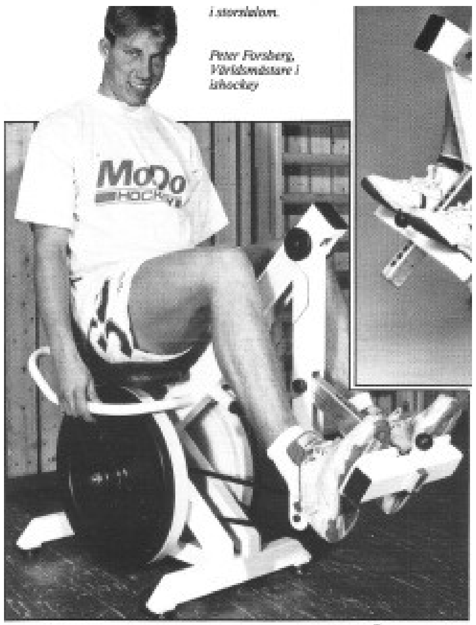


Inertial Training by turning a flywheel via the use of elbow flexion (Verkhoshansky, 1977).

Thus, in the second case, it is easy to appreciate the possibility for overcoming the opposing tendency between the weight of the load and the speed of muscular contraction. Unfortunately, the necessary specialised equipment for producing muscular work to overcome the inertia of a load is rarely used in training. However, to extend the methods of special strength training, one must consider this concept of *inertial training* more seriously.

Science meets practice…

A Gravity-Independent Ergometer to be Used for Resistance Training in Space



SPACE EXERCISE EQUIPMENT—BERG & TESCH

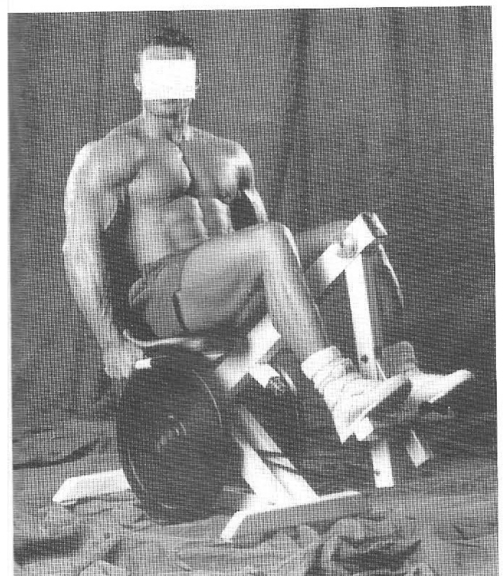
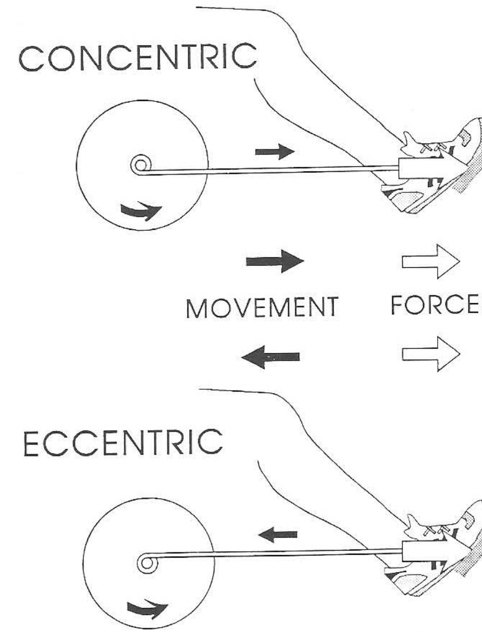


Fig. 1. A gravity-independent inertia ergometer for resistance training in space.



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Importance of eccentric actions in performance adaptations to resistance training

Author and Affiliation:	Dudley, Gary A.	*(Bionetics Corp., Cocoa Beach, FL, United States)*
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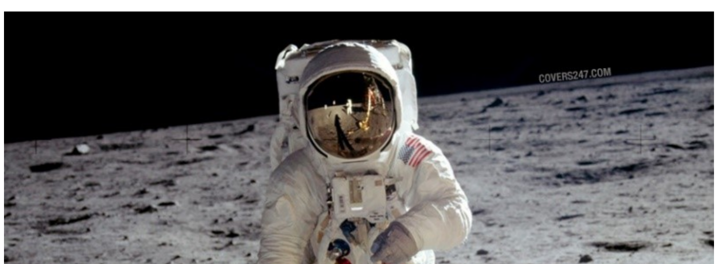
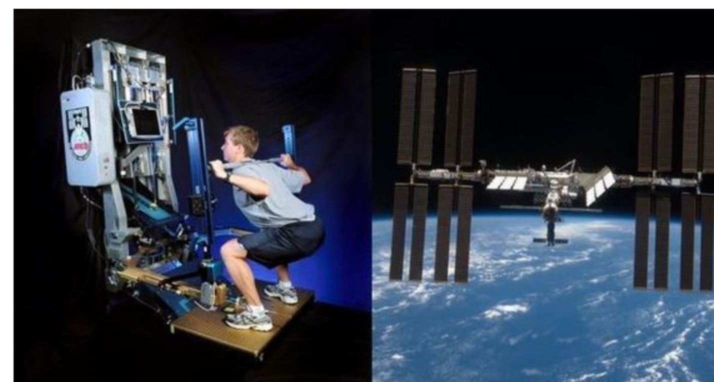
Abstract:	The importance of eccentric (ecc) muscle actions in resistance training for the maintenance of muscle strength and mass in hypogravity was investigated in experiments in which human subjects, divided into three groups, were asked to perform four-five sets of 6 to 12 repetitions (rep) per set of three leg press and leg extension exercises, 2 days each weeks for 19 weeks. One group, labeled 'con', performed each rep with only concentric (con) actions, while group con/ecc with performed each rep with only ecc actions; the third group, con/con, performed twice as many sets with only con actions. Control subjects did not train. It was found that resistance training wih both con and ecc actions induced greater increases in muscle strength than did training with only con actions.	
Publication Date:	Jun 01, 1991	
Document ID:	19910054917	*(Acquired Nov 28, 1995)*



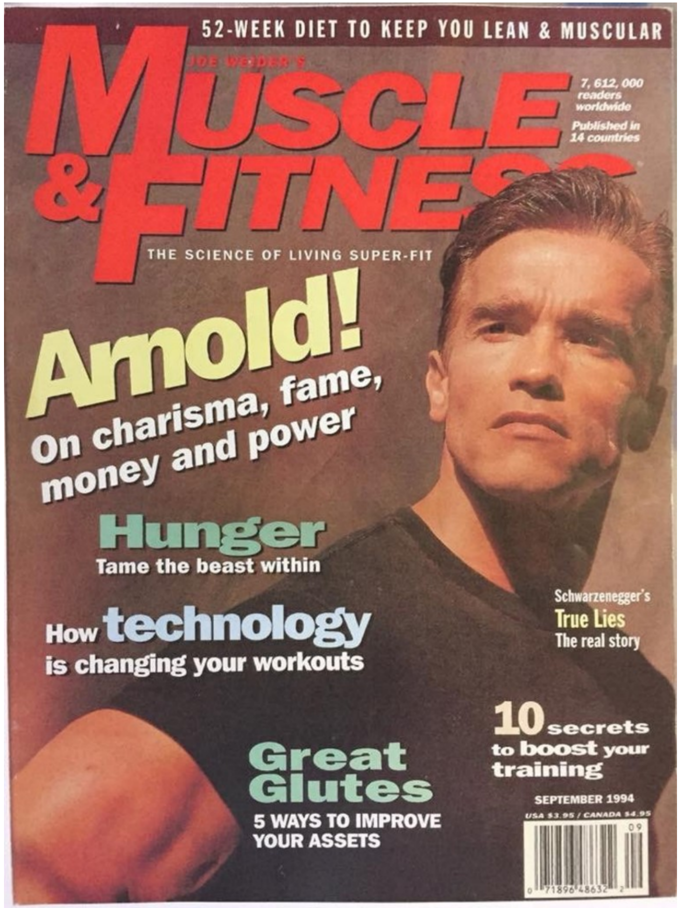
YO-YO FITNESS TRAINER, USING A FLYWHEEL TO CREATE THE FORCE AGAINST WHICH TO TRAIN

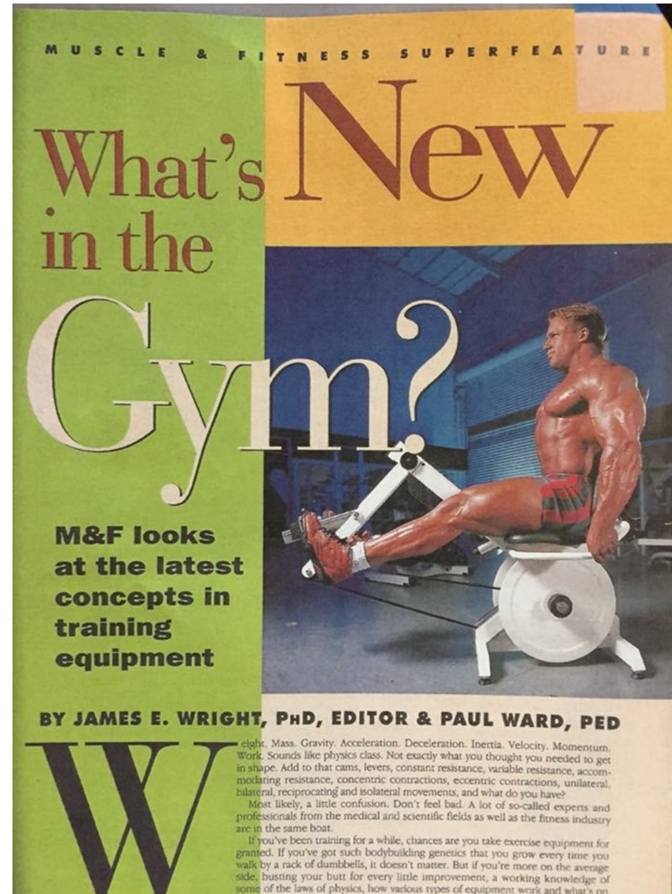
Science



Hur gör man en knäböj i rymden?

Science meets practice…





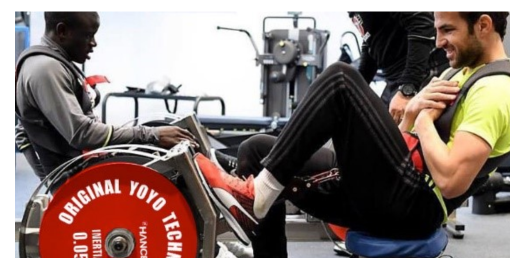
Weight. Mass. Gravity. Acceleration. Deceleration. Inertia. Velocity. Momentum. Work. Sounds like physics class. Not exactly what you thought you needed to get in shape. Add to that cams, levers, constant resistance, variable resistance, accommodating resistance, concentric contractions, eccentric contractions, unilateral, bilateral, reciprocating and isolateral movements, and what do you have?

Most likely, a little confusion. Don't feel bad. A lot of so-called experts and professionals from the medical and scientific fields as well as the fitness industry are in the same boat.

If you've been training for a while, chances are you take exercise equipment for granted. If you've got such bodybuilding genetics that you grow every time you walk by a rack of dumbbells, it doesn't matter. But if you're more on the average side, busting your butt for every little improvement, a working knowledge of some of the laws of physics, how various types of equipment work and what's on the market today can make your workouts more enjoyable and productive

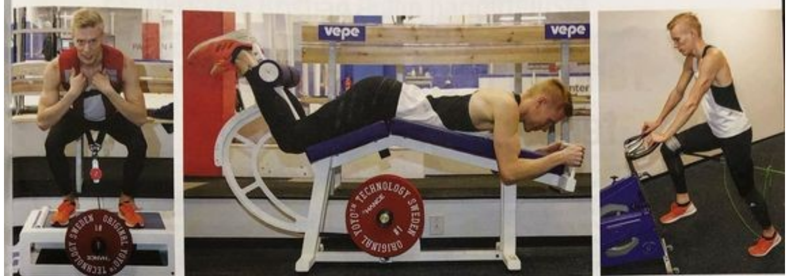
Science meets practice…

Science meets practice…



Science meets practice…

Science meets practice…



Kristian Pulli kokeili voimaharjoittelua Tampereen HDC-keskuksen flywheel-laitteilla peruskuntokaudella ja aikoo hyödyntää laitteita myös jatkossa.

Pulli testasi kuukauden verran flywheel-harjoittelua

Kuluneen talven voimaharjoittelussa **Kristian Pulli** kokeili Tampereen Jääkiekon kehittämiskeskuksessa (Hockey Development Center, HDC) flywheel-harjoittelua eli voimaharjoittelua, jossa vastus syntyy vauhtipyörän muodostamasta liike-energiasta. Vastusta säädellään liikenopeudella. Mitä rajummin vauhtipyörää kiihdyttää, sitä kovempi on vastus. Kun vastus toimii myös liikkeen palautusvaiheessa, saadaan aikaiseksi vahva eksentrinen harjoitusvaikutus.

– Kun liike-energia kelaa remmin takaisin, se tulee ylikuormalla, jolloin saadaan tehostettua eksentrisen voimantuoton vaihetta, kertoo HDC-keskuksen toimitusjohtaja ja valmentaja **Sasu Hovi**.

– Vastus muuttuu sen mukaan, miten urheilija pystyy tuottamaan voimaa lisää, eli se ei lopu siihen, kun painomassa on saatu liikkeelle kuten levytangon kanssa. Näillä laitteilla urheilija pystyy kelaamaan koko ajan lisää vastusta ja saamaan aikaiseksi koko liikealueen kattavan vastuksen, ja vielä niin, että vastus tulee yhdestä pisteestä eikä ole naimisissa painovoiman kanssa.

Kun vastus tulee yhdestä pisteestä, se mahdollistaa Hovin mukaan sen, että vastusta päästään tuomaan eri lajien kannalta oikeasta suunnasta.

– Jääkiekkoa ajatellen pystytään tekemään esimerkiksi luistelun puristus ja potku -yhdistelmä. Jääkiekossa se on isoin loukkaantumisia estävä tekijä, kun voidaan tehdä luistelupotkun palautusta voimaliikkeenä.

Kuormitusta säännösteltävä tarkasti

Pullia flywheel-harjoittelusta kiinnosti nimenomaan eksentrisen voimantuoton kehittäminen ja räjähtävän voiman hankinta.

– Eksentrinen voimantuotto kehittää lihasta enemmän ja nopeammin kuin konsentrinen, koska jarruttaminen on lihastyönä tehokkaampaa. Haettiin sitä, että kehitetään lihasta tietty aika ja yritetään saadaan sinä aikana aikaiseksi maksimaalinen kehitys, Pulli kertoo.

Flywheel-kokeilujakson aikana Pulli ei halunnut karsia muusta voimaharjoittelusta. Hän teki Pirkkahallilla ensin normaalin voimatreenin ja sen päälle flywheel-harjoituksen HDC-keskuksessa. Kokeilun hän rajoitti sen rasittavuuden takia neljän viikon mittaiseksi ja ajoitti sen peruskuntokaudelle.

– Sen treenijakson jälkeen tuntui, että kaikki meni monttuun. Ominaisuustasot olivat alhaisemmalla tasolla kuin pitkään aikaan, mutta pari viikkoa siitä, kun kokeilu lopetettiin, ominaisuudet nousivat vuodenaikaan nähden aivan huipputasolle, Pulli kertoo.

– Käytän flywheel-harjoittelua myös jatkossa, mutta niin, että vähennän muuta voimaharjoittelua. Flywheel-harjoittelu on tosi kuormittavaa ja kuormituksen tasoa pitää säännöstellä tarkasti. Itse mittasin treenissä tehowatit jokaisesta suorituksesta. Irtioton määrä oli tosi kova.

Flywheel-harjoitukset Pulli kohdisti jalkojen lihaksistoon, eli flywheel-laitteilla tehtiin kyykkyä ja jalkaprässiä simuloivia harjoitteita ja kuormitettiin erikseen takareisien ja lonkankoukistajien lihaksistoa.

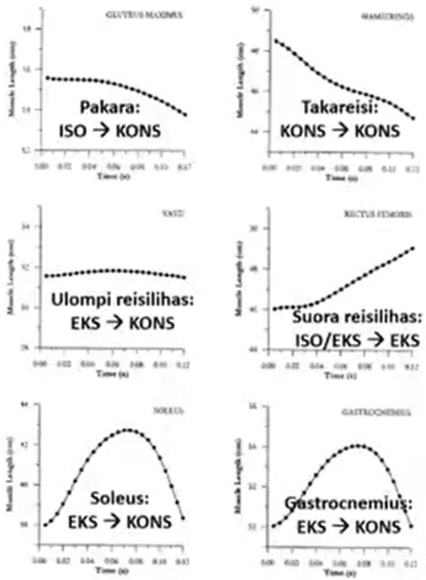
– Jotakin uutta täytyy aina koettaa etsiä. Nähtiin, että ruotsalaiset pikajuoksijat käyttävät sitä ja ajateltiin, että voisi olla hyvä itsellekin kokeilla, Pulli sanoo.

Science meets practice…

Eksentrinen voimaharjoittelu

Tampereen URHEILUAKATEMIA

Miksi? Lajianalyysi



Lihasjännekompleksin pituuden muutokset pituushypyn ponnistuksessa (Hay et al. 1999)

Lihasjännekompleksin nopealla venymisellä ja siten suurella **eksentrisellä voimantuotolla** ponnistuksen alkuvaiheessa ("jarrutusvaihe") on suurempi merkitys ponnistuksen loppuvaiheen ("työntövaihe") nopeuteen kuin venymis-lyhenemissyklin kautta tapahtuvalla loppuvaiheen lihastyöllä (Hay et al. 1999).

Miksi? Harjoitteluanalyysi

- Korkealla tasolla olevat urheilijat tarvitsevat uusia harjoitusärsykkeitä kehittyäkseen ja eksentrisen voimantuoton suuruuden ja/tai eksentrisen supistusnopeuden lisääminen on todettu tähän hyväksi vaihtoehdoksi korkean voimatason omaavilla urheilijoilla (Suchomel et al. 2019).
- Eksentrisen voimaharjoittelun on todettu aiheuttavan suurempaa kehittymistä kuin perinteisen voimaharjoittelun (Douglas et al. 2017):
  - Lihaksen voimantuotto-ominaisuudet (maksimivoima, tehontuotto, venymis-lyhenemissykli) kehittyy
  - Lihaksen neuraalinen ohjaus parantuu (erityisesti nopeat motoriset yksiköt)
  - Lihasarkkitehtuurin muutokset: Lihasmassan lisääntyminen lihassolujen pituuskasvun myötä (erityisesti nopeat lihassolut) → lihaksen supistumisnopeus kasvaa ja voimantuotto suurilla lihaspituuksilla kasvaa
  - Lihaksen morfologian mahdollinen muutos nopean IIX-solutyypin suuntaan
  - Lihas-jänne-kompleksin ominaisuudet (jänteen jäykkyyden ja paksuuden kasvu) kehittyy

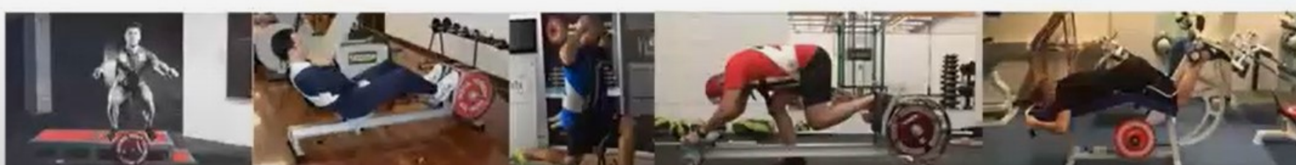
TAMPERE. FINLAND VARALA

Science meets practice…

Tampereen URHEILUAKATEMIA

Flywheel-harjoittelu

- Flywheel-harjoittelun on todettu olevan potentiaalinen ja tehokas menetelmä konsentrisen ja eksentrisen maksimivoiman, lihasmassan, tehontuoton ja lajin suorituskyvyn (horisontaalinen / vertikaalinen nopea voimantuotto) kehittämiseen (Petre et al. 2018)
- Mahdollisesti tehokkaampi tapa kehittää voimantuotto-ominaisuuksia (maksimivoima, lihasmassa ja erityisesti tehontuotto) ja lajin suorituskykyä (juoksu, ponnistaminen) kuin perinteinen voimaharjoittelu (Maroto-Izquierdo et al. 2017)
- Tehokkaampi harjoitusmuoto kokeneilla voimaharjoittelijoilla verrattuna kokemattomampiin maksimivoiman ja tehontuoton kehittämisessä (Petre et al. 2018)
- Suosituksia
  - Korkeat vastukset maksimivoiman kehittämiseksi (Beato & Iacono 2020; Martinez-Aranda & Fernandez-Gonzalo 2017)
  - 3-6 sarjaa, 6-8 toistoa, 2-3 kertaa viikossa, vähintään 4-5 viikon ajan (Beato & Iacono 2020)
  - vähintään 3 min palautumisajat tehontuoton maksimoimiseksi (Sabido et al. 2020)



VARALA

Science meets practice…

Tampereen URHEILUAKATEMIA

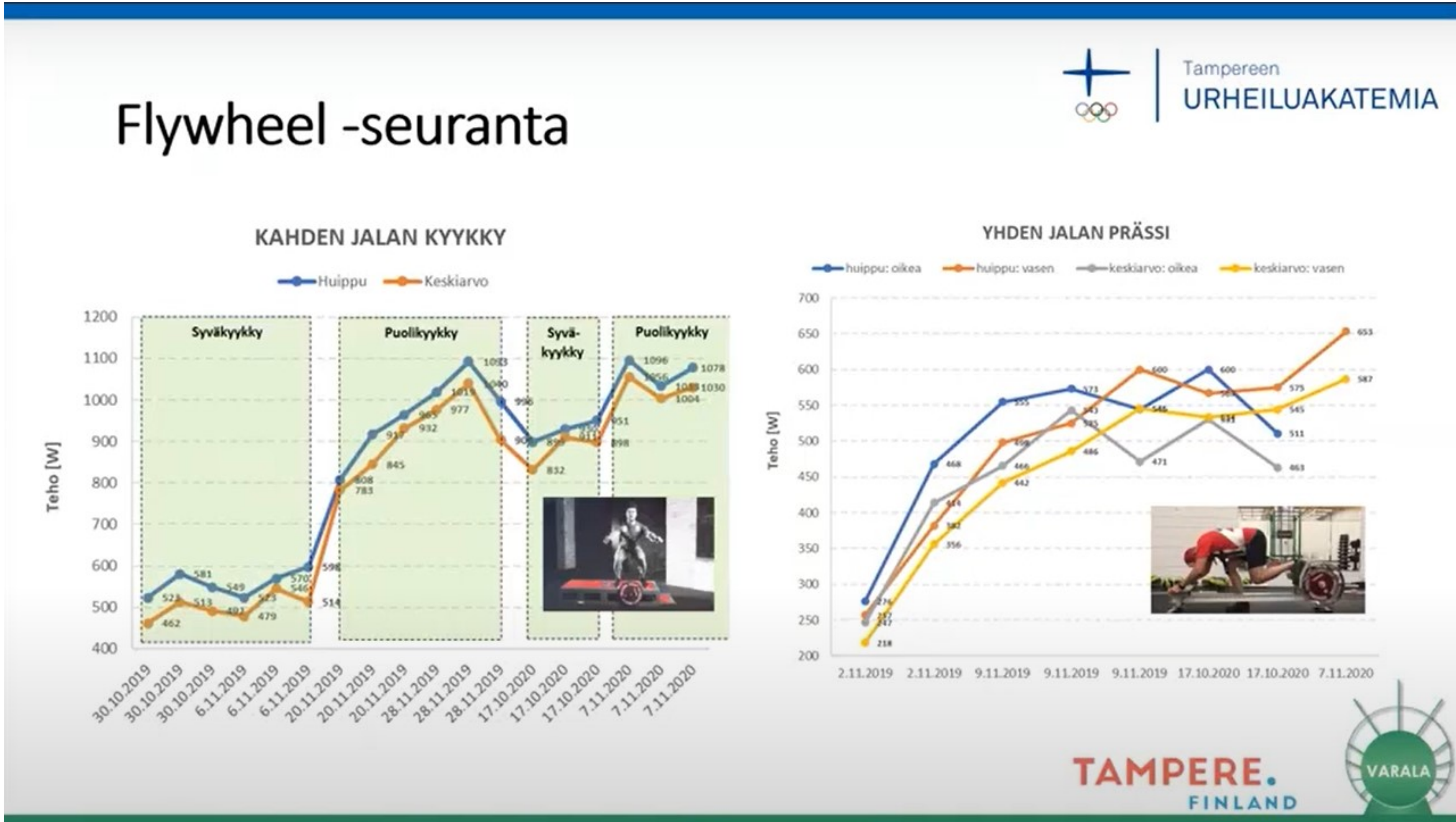
Flywheel -progressio

Harjoitus 1	Viikko 1	Viikko 2	Viikko 4	Viikko 5
Kahden jalan kyykky	3x5 Vastus #2+1	3x5 Vastus #2+2	3x4 Vastus #2+2+1	3x3 Vastus #2+2+2
Pohkeet	3x5 Vastus #2+1	3x5 Vastus #2+2	3x4 Vastus #2+2+1	3x3 Vastus #2+2+2
Lonkankoukistajat	3x(5+5) Vastus -3	3x(5+5) Vastus -2	3x(4+4) Vastus -1	3x(3+3) Vastus 0
Harjoitus 2	**Viikko 1**	**Viikko 2**	**Viikko 4**	**Viikko 5**
Yhden jalan kyykky	3x(5+5) Vastus #2+1	3x(5+5) Vastus #2+2	3x(4+4) Vastus #2+2+1	3x(3+3) Vastus #2+2+2
Yhden jalan prässi	3x(5+5) Vastus #2	3x(5+5) Vastus #2+1	3x(4+4) Vastus #2+2	3x(3+3) Vastus #2+2+1
Takareidet	3x(3+3) Vastus #2+2	3x(3+3) Vastus #2+2	3x(2+2) Vastus #2+2	3x(2+2) Vastus #2+2

TAMPERE. FINLAND

VARALA

Science meets practice…



SUBJECTS

- Eighteen homogenous male Finnish elite ice-hockey players (U18-U21)
- Players were recruited and assigned by the coaches to an experimental (FG) n=9 or control group (CG) n=9
- All subject gave their written consent after a detailed explanation about the aims, benefits, and risks involved in this study

Table 1

Descriptive data of the subjects.*†

	Age (y)	Height (cm)	Body mass (kg)	Body fat (%)	BMI (kg/m^2)
FG group	18.9 ± 1.0	180.0 ± 7.8	80.0 ± 9.1	12.9 ± 2.6	24.7 ± 2.0
TG group	18.3 ± 0.5	182.7 ± 11.1	77.7 ± 10.7	11.7 ± 2.7	23.3 ± 3.1

*BMI = body mass index; FG = flywheel group; TG, traditional training group.
†Data are mean and *SDs*.

EXCLUSION CRITERIA

- Training facility not available during the intervention
- Injuries or illness that interfere with strength training
- Earlier experience of FW training

DATA COLLECTION

- Took place during the first pretest sessions right before the off-season training period and during the posttest sessions after the training period.
- All the tests were executed and registered by the director of Varala Testing Lab, M.Sc Marko Haverinen in Varala Sports Institute, Tampere, Finland.
- None of the participants had previously used FW devices but had several years of strength training background with free weights.

STUDY DESIGN

- The subjects completed a conventional strength and power training period lasting for 8 weeks from June to July in 2016 or 2017 during their off-seasonal training phase.
- Homogenous subjects performed identical strength and power training period during their off-seasonal training phase with the exception that FG strength and power training were carried out using flywheel machines.

STUDY DESIGN

- Familiarization sessions (2) with the flywheel devices and exercises used in the study were allowed and supervised.
- In the first training week session, the EG group performed a test where the inertia used during the intervention (first 4 training weeks) with the FW squat machine was selected based on best average CON power output of the set.
- This inertia was then readjusted after 4 weeks of training for optimizing individual maximal power for the squat exercises.

STUDY DESIGN

FG
TOTAL REPS START/END 72/224 !
TOTAL VOLUME INCREASE 211%
3,1 X VOLUME FROM THE START
~ 8 WEEKS !

CG
TOTAL REPS START/END 144/104 !
TOTAL VOLUME DECREASE 28%
0,7 X VOLUME FROM THE START
~ 8 WEEKS !

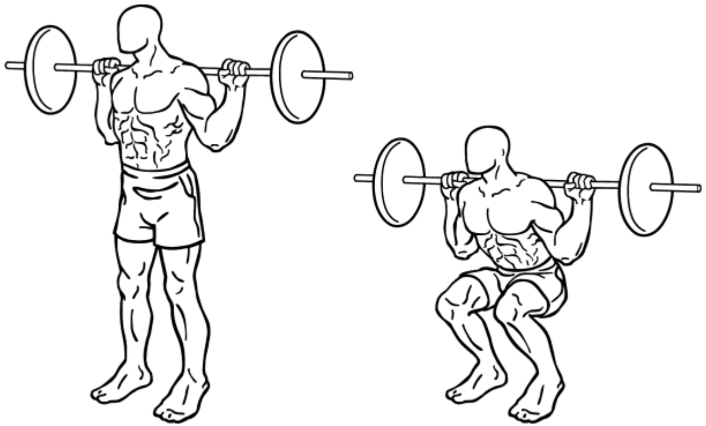
Training protocol EG					
	Weeks	Sessions	Sets	Repetitions	Interval
	1-2	1	3	6	3 min
	3-4	2	3	6	3 min
	5-6	2	4	6	3 min
	7-8	2	4	7	3 min
Training protocol CG					
Exercises	Weeks	Sessions	Sets	Repetitions	Interval
Back Squat/ Power Clean	1-2	1	4	12+10+8+6	3 min
Pistol Squat	1-2	1	4	8+8	3 min
Walking Lunge	1-2	1	4	10+10	3 min
Back Squat/ Power Clean	3-8	2	4	8+6+6+4	3 min
Pistol Squat	3-8	2	4	6+6	3 min
Walking Lunge	3-8	2	4	8+8	3 min

Kuvat/videot: Jari Puustinen

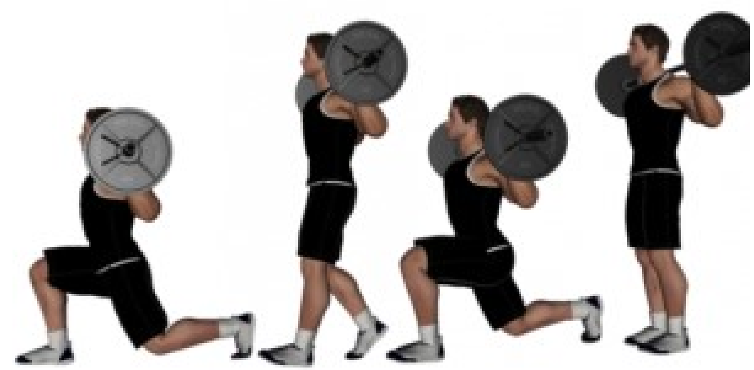
Viikko 23 1 harjoitus 4 liikettä 3x6 toistoa	Viikko 24 1 harjoitus 4 liikettä 3x6 toistoa	Viikko 25 2 harjoitusta 4 liikettä 3x6 toistoa	Viikko 26 2 harjoitusta 4 liikettä 3x6 toistoa
Viikko 27 2 harjoitusta 4 liikettä 4x6 toistoa	Viikko 28 2 harjoitusta 4 liikettä 4x6 toistoa	Viikko 29 2 harjoitusta 4 liikettä 4x7 toistoa	Viikko 30 2 harjoitusta 4 liikettä 4x7 toistoa

JOKAINEN TOISTO SARJASSA TEHDÄÄN **TÄYSILLÄ** ALL OUT PERIAATTEELLA. LIIKE ON KOKO SARJAN AJAN JATKUVA JA TYÖVAIHE ON NÄIN OLLEN LYHYT MUTTA KOKO SARJAN MITTAINEN. ALKUUN VOI OLLA MUUTAMA KEVYT TOISTO JOILLA HAETAAN HYVÄ ASENTO, OIKEA REMMIN PITUUS JA VAUHTIPYÖRÄÄN VAUHTIA JA SEN JÄLKEEN ALKAA VASTA VARSINAINEN SARJA! ALKUUN VOI TEHDÄ YHDEN LÄMMITTELY SARJAN ESIM. KEVYEMMÄLLÄ KIEKOLLA JA MUISTA LÄMMITELLÄ HYVIN ENNEN HARJOITUSTA. SARJATAUKO ON **3 MINUUTTIA** JA LIIKKEIDEN VÄLISSÄ **3-5 MINUUTTIA**. TEE NÄIDEN LIIKKEIDEN (4 KPL) LISÄKSI MUUT OMASSA OHJELMASSA OLEVAT TAI VALMENTAJAN KANSSA SOVITUT LIIKKEET JA HARJOITTEET. **VALITSE SOPIVA VASTUS KYYKKYLAITTEESEEN TESTIEN JA OHJEIDEN PERUSTEELLA. TAKAREISI- JA JALKAPRÄSSILAITTEISSA VASTUS PYSYY SAMANA KOKO HARJOITUSJAKSON!** HARJOITUSTEN VÄLISSÄ TULISI OLLA VÄHINTÄÄN 48 TUNTIA TAUKOA, MIELUMMIN 3-4 PV!

Kuvat/videot: Jari Puustinen




BULLDOG GEAR
BULLDOG GEAR

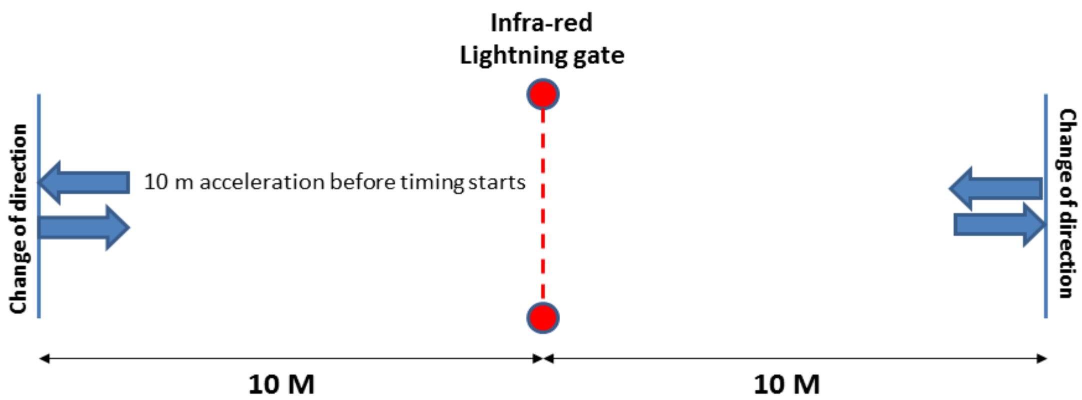


Training protocol CG					
Exercises	Weeks	Sessions	Sets	Repetitions	Interval
Back Squat/ Power Clean	1-2	1	4	12+10+8+6	3 min
Pistol Squat	1-2	1	4	8+8	3 min
Walking Lunge	1-2	1	4	10+10	3 min
Back Squat/ Power Clean	3-8	2	4	8+6+6+4	3 min
Pistol Squat	3-8	2	4	6+6	3 min
Walking Lunge	3-8	2	4	8+8	3 min

- Linear periodization model with the possibility to daily undulate the resistance as high as tolerated.
- Loads for back squat and power clean were chosen after the pretest session
- Loads for the pistol squat and walking lunge were determined by the load that was closest for the given repetition.

PERFORMANCE TESTS

- Jumps → CMJ with 0, 20 & 40 kg extra weights
- Runs → maximal 200-m sprint→change of direction in every 20 meters
- Power output → FG with flywheel machine



STATISTICAL ANALYSIS

- Data are presented as mean ± SD.
- Mean and standard deviation (SD) were calculated for all variables.
- Variables were analyzed by a 2-way analysis of variance (ANOVA) with repeated measurements: group (FG and CG) and time (pre- and post-training) and follow-up comparisons were made with paired t-tests within each group.
- Statistical significance was set at $p \leq 0.05$.

RESULTS

Table 2

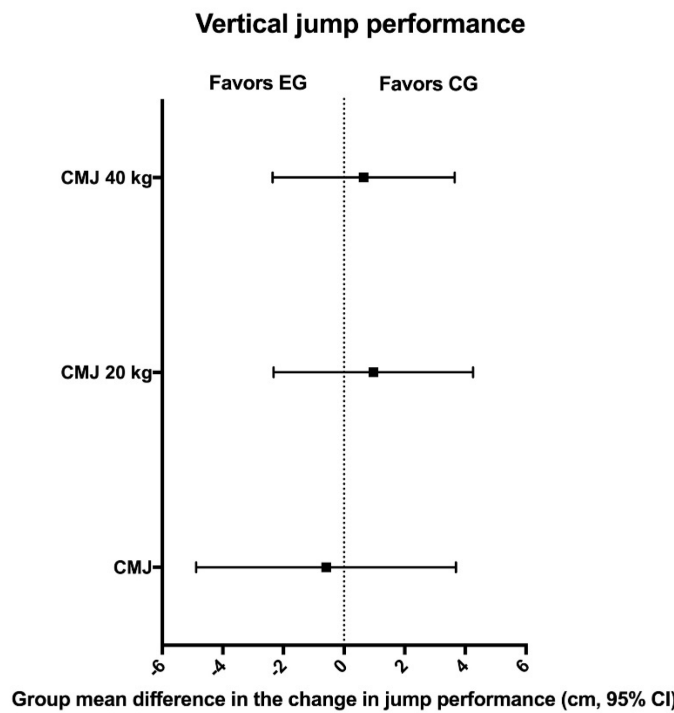
Outcome variables before (PRE) and after (POST) 8 weeks esistance training in the FG and TG. an ± *SD*.*†

	FG			TG			Group effect		
Variable	PRE	POST	Δ%	PRE	POST	Δ%	*F*	*p*	Cohen's *d*
CMJ (cm)	41.6 ± 4.0	43.8 ± 3.2	5.7	42.1 ± 2.6	44.1 ± 5.6	4.8	0.000	0.986	0.009
CMJ 20 kg (cm)	30.2 ± 2.6	32.4 ± 2.9	7.3	29.5 ± 2.8	32.7 ± 4.8	11.1	0.432	0.522	−0.323
CMJ 40 kg (cm)	23.4 ± 2.6	24.8 ± 2.7	6.1	22.8 ± 2.5	24.8 ± 4.1	9.2	0.117	0.738	−0.174
10 + 10 m sprint (s)	4.11 ± 0.08	3.99 ± 0.11	−3.2	4.05 ± 0.07	3.94 ± 0.06	−2.6	0.000	0.994	0.004
2 × 10 + 10 m sprint (s)	8.26 ± 0.19	8.03 ± 0.20	−3.0	8.13 ± 0.14	7.92 ± 0.10	−2.6	0.093	0.765	0.161
3 × 10 + 10 m sprint (s)	12.45 ± 0.25	12.12 ± 0.31	−2.7	12.31 ± 0.17	12.00 ± 0.16	−2.5	0.015	0.905	0.063
4 × 10 + 10 m sprint (s)	16.68 ± 0.41	16.30 ± 0.42	−2.3	16.55 ± 0.23	16.13 ± 0.25	−2.5	0.433	0.521	0.326
5 × 10 + 10 m sprint (s)	21.04 ± 0.48	20.49 ± 0.58	−2.5	20.82 ± 0.31	20.36 ± 0.30	−2.2	0.030	0.864	−0.088
6 × 10 + 10 m sprint (s)	25.39 ± 0.58	24.74 ± 0.67	−2.5	25.17 ± 0.36	24.68 ± 0.36	−1.9	0.345	0.567	−0.292
7 × 10 + 10 m sprint (s)	29.77 ± 0.68	29.10 ± 0.87	−2.0	29.60 ± 0.41	29.04 ± 0.45	−1.9	0.044	0.837	−0.102
8 × 10 + 10 m sprint (s)	34.27 ± 0.74	33.46 ± 0.99	−2.2	34.06 ± 0.45	33.42 ± 0.52	−1.9	0.191	0.668	−0.214
9 × 10 + 10 m sprint (s)	38.77 ± 0.80	37.89 ± 1.12	−2.1	38.47 ± 0.52	37.91 ± 0.63	−1.4	1.03	0.327	−0.500
10 × 10 + 10 m sprint (s)	43.24 ± 0.84	42.33 ± 1.23	−1.8	43.05 ± 0.62	42.41 ± 0.72	−1.5	0.361	0.558	−0.292
20 to 40 m split (s)	4.15 ± 0.15	4.01 ± 0.12	−3.4	4.08 ± 0.12	3.97 ± 0.07	−2.7	0.031	0.863	0.088
40 to 60 m split (s)	4.19 ± 0.10	4.07 ± 0.12	−2.8	4.18 ± 0.07	4.03 ± 0.09	−3.4	0.328	0.576	0.279
60 to 80 m split (s)	4.23 ± 0.24	4.13 ± 0.12	−1.8	4.24 ± 0.08	4.12 ± 0.10	−2.8	0.181	0.677	0.207
80 to 100 m split (s)	4.36 ± 0.16	4.20 ± 0.18	−3.3	4.27 ± 0.10	4.20 ± 0.10	−1.5	0.000	0.979	0.014
100 × 120 m split (s)	4.35 ± 0.12	4.24 ± 0.13	−2.5	4.35 ± 0.08	4.28 ± 0.09	−1.5	1.09	0.312	−0.509
120 to 140 m split (s)	4.37 ± 0.17	4.32 ± 0.25	−0.6	4.43 ± 0.12	4.35 ± 0.10	−1.8	0.031	0.862	0.091
140 to 160 m split (s)	4.50 ± 0.11	4.32 ± 0.16	−3.8	4.46 ± 0.11	4.39 ± 0.09	−1.6	2.52	0.135	−0.778
160 to 180 m split (s)	4.51 ± 0.16	4.39 ± 0.16	−1.8	4.41 ± 0.22	4.45 ± 0.14	0.9	1.03	0.327	−0.501
180 to 200 m split (s)	4.47 ± 0.15	4.43 ± 0.13	−0.3	4.58 ± 0.22	4.49 ± 0.14	−1.9	0.051	0.825	−0.117

*FG = flywheel group; TG = traditional training group; CMJ = countermovement jump; ANCOVA = analysis of covariance.
†The group effect was examined using ANCOVA with the POST-score as a dependent variable and the PRE-score as a covariate.

JUMPS

Both protocols showed comparable increases in CMJ, CMJ +20kg and CMJ +40kg height (Figure 4). No significant group by time interaction or within-group differences were observed for the CMJ test (p=0.863). Within-group differences for the CMJ were in the EG 5.7 ± 6.9%; p = 0.057, and in the CG group 4.8 ± 12.2%; p = 0.265 (Figure 5).



RUNS

There was no significant group by time interaction in 20 meters sprint time (p=0.517). Planned comparisons of the 20 m sprint test revealed significant within-group changes in both groups (EG: -3.2 ± 1.7%, p = 0.001 vs. CG: - 2.6 ± 2.2%, p = 0.008). Figure 8 shows the 20 m sprint times before and after the intervention and mean change.

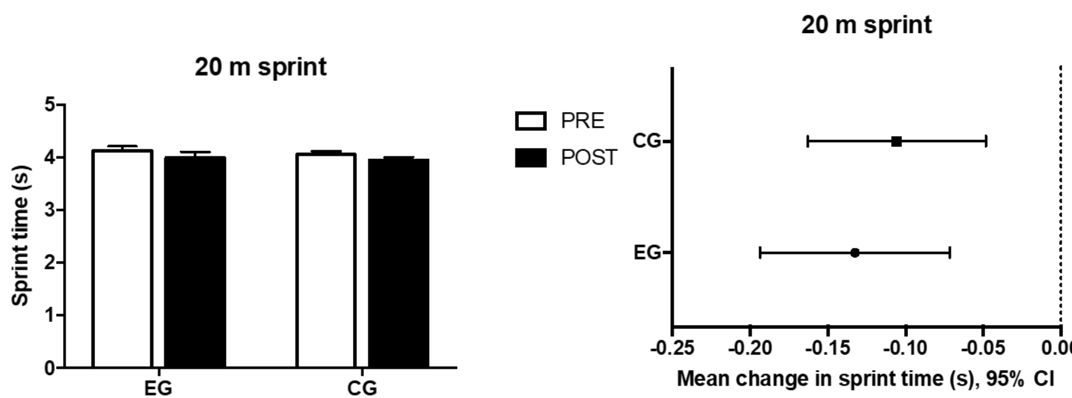


Figure 8. Pre- and Post-training 20 meters sprint time and mean change. No significant group by time interaction (p > 0.05). Significant planned comparisons within-group differences in CG (p < 0.05). Significant planned comparisons within-group differences in EG (p < 0.01).

RUNS

There was no significant group by time interaction in 40 meters sprint time ($p=0.605$). Significant within-group differences were observed in the EG (-3.0 ± 1.3%; $p < 0.001$) and CG group (-2.6 ± 1.9%; $p = 0.003$). Figure 9 shows the 40 meters sprint time (s) results before and after the intervention and mean change.

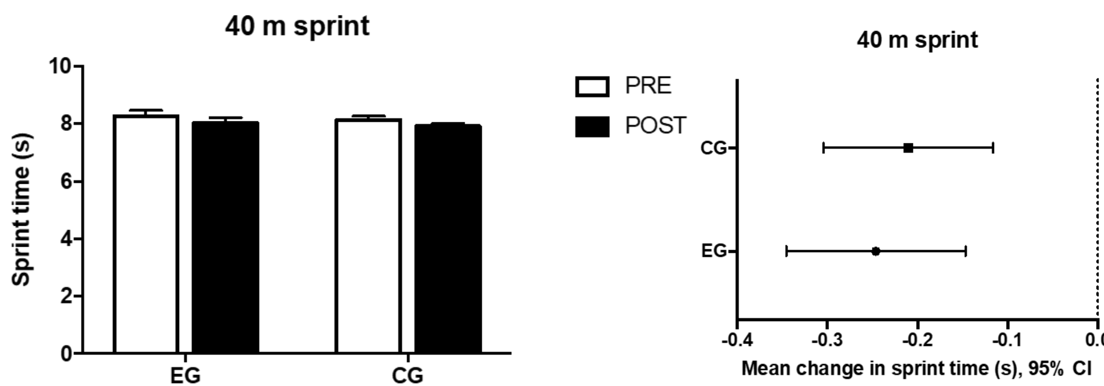


Figure 9. Pre- and Post-training 40 meters sprint time and mean change. No significant group by time interaction ($p > 0.05$). Significant planned comparisons within-group differences in both groups ($p < 0.01$).

RUNS

There was no significant group by time interaction in 200 meters total sprint time ($p=0.572$). Significant within-group differences were observed in the EG (-1.8 ± 1.6%; $p = 0.013$) and CG group (-1.5 ± 1.0%; $p = 0.002$). Figure 10 shows results before and after the intervention and mean change.

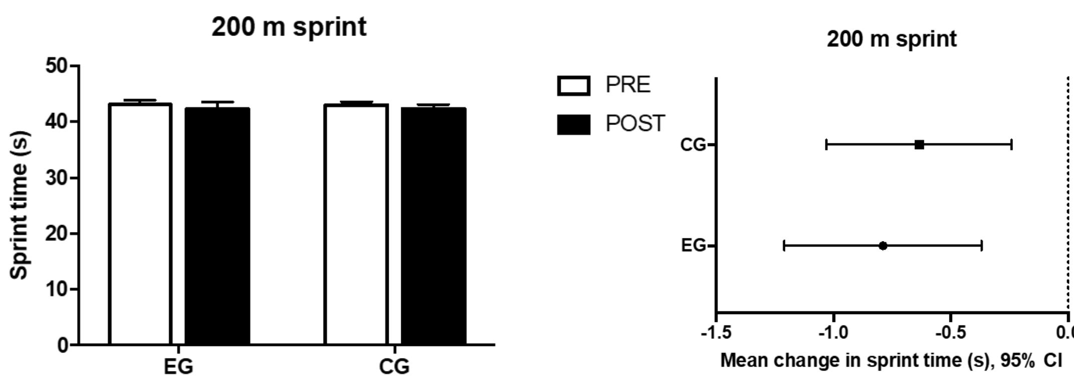
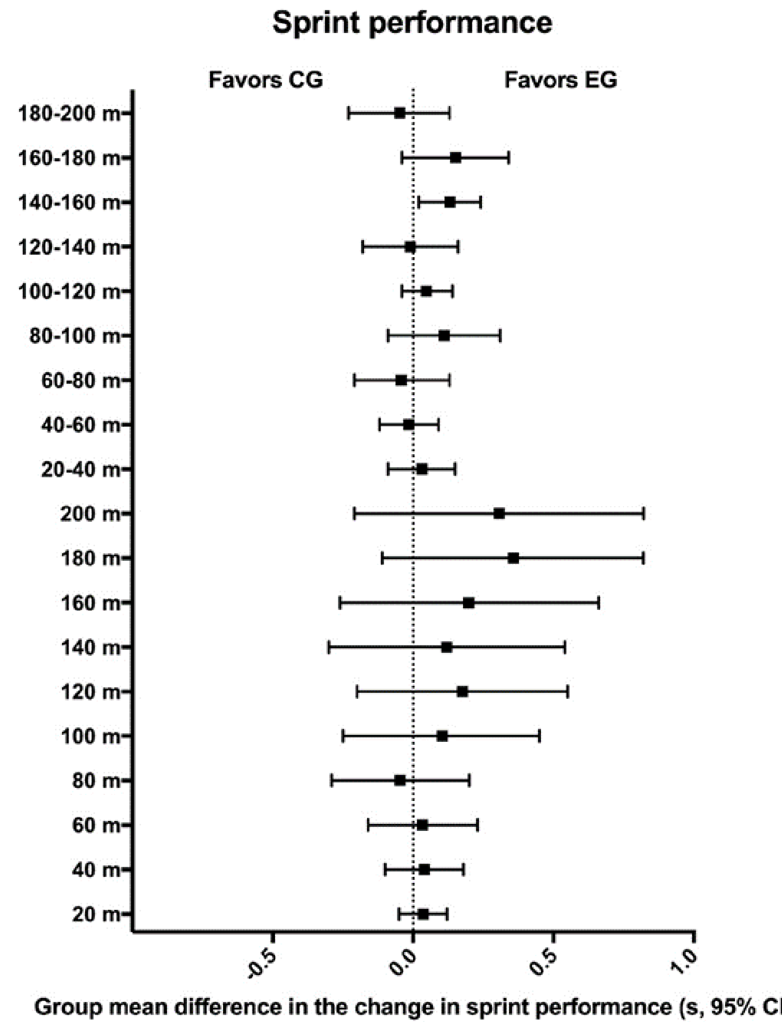


Figure 10. Pre- and Post-training 200 meters sprint time and mean change. No significant group by time interaction ($p > 0.05$). Significant planned comparisons within-group differences in EG ($p < 0.05$). Significant planned comparisons within-group differences CG ($p < 0.01$).

RUNS

- The fatigue profile was similar between the groups.
- Furthermore, speed and COD profile i.e. first two shuttles improvements, were similar between the groups without any significant group by time interaction.
- Similar findings were found in speed endurance profile.
- In summary, even though FG improved 14/19 of the running test total or split times results more than CG, there were no group x time interactions.



POWER OUTPUT

In the maximal power output test for the EG, there were significant within-group differences on 5RM (33 ± 23 %; p = 0.012) and peak repetition (31 ± 25 %; p = 0.018) AVG power development (W). Figure 12. shows the results before and after the intervention.

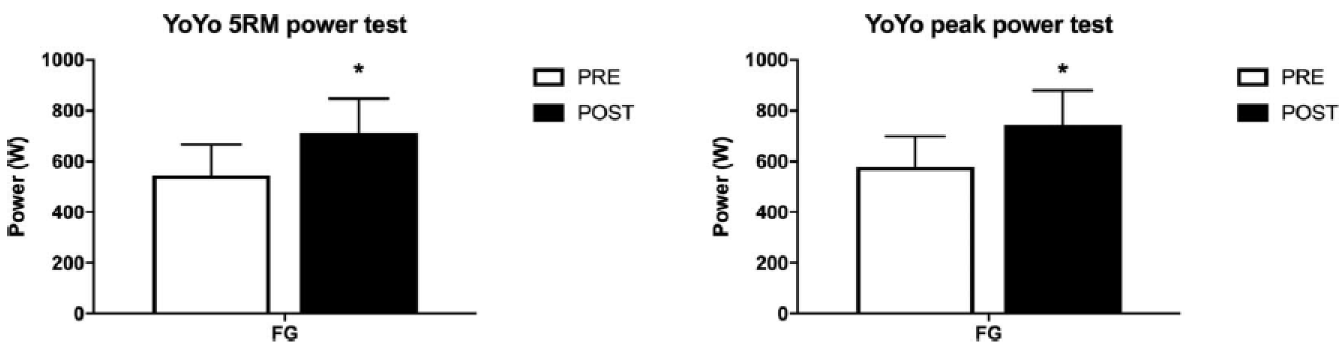


Figure 1. Pretraining and post-training power output (W) 5 repetition and 1 repetition peak average power and mean change. *Significant within-group differences ($p < 0.05$).

DISCUSSION

- The current study shows that FW training is an effective method for improving several aspects of strength and power with relevance for ice-hockey performance.
- Substantial improvements in capacities highly related to athletic performance, such as vertical jump height, running speed and endurance as well as power output.
- These findings are supported by previous meta-analyses (Petre et al. 2018, Maroto-Izquierdo et al. 2017a) where several aspects of neuromuscular performance have been shown to be enhanced by FW training.

IN PRACTICE..

- 8 weeks of FW training →
- Performance improvements → 5–7% in the CMJ tests
- Performance improvements → 1.5–3.2% in the sprint tests
- Performance improvements → ~33% in power output of bilateral squat
- Performance improvements → 3% in the 20 and 40 meter sprint times
- Performance improvements → 1.5% in the 200 meter sprint

IN PRACTICE..

- Based on current evidence, FW training seems to be an effective training method for improving jumping and sprinting performance in elite ice hockey players.
- There is some evidence in the research literature that more experienced athletes using eccentric overload training could achieve superior performance gains and muscle adaptations with FW.
- The repeated negative actions with the FW machines may lead to better improvement in braking ability and thus better change of-direction ability compared to traditional barbell training
- The ability to produce eccentric overload in the FW system appears to require some previous experience with the training method

IN PRACTICE..

- Flywheel training has been shown to be efficient in enhancing individual performance enhancement of team sport athletes, where players are often required to perform repeated high-intensity actions.
- Most likely, free weights, FW machines, and other resistance training modalities all have their role and benefits in athletic development.
- Therefore, coaches and athletes should consider using a variety of different training methods to improve performance of ice hockey players.
- There are several ways to manipulate the ECC load if players can tolerate more ECC force and are adapted with the traditional FW resistance training paradigm.

Practical Applications

Based on the results of this experimental training study, it is concluded that both FW and conventional resistance training improve performance proxies relevant to ice hockey players. There were no group differences in training effects, suggesting that improvements were similar across groups. Thus, although FW training seems to be an effective training method for improving neuromuscular performance in elite ice hockey players, it does not result in superior performance improvements compared with conventional resistance training in players with no prior experience with this training method.

Take Home Message

- Several methods to train with Flywheel, not only delayed eccentric
- Manipulate ECC load as/when possible
- Performance enhancement, prevention, rehabilitation etc.

Evidence Based Practice

Effect of eccentric overload training on change of direction speed performance: A systematic review and meta-analysis

Ruidong Liu , Jianxiu Liu , Caitlin Vitosky Clarke & Ruopeng An

To cite this article: Ruidong Liu , Jianxiu Liu , Caitlin Vitosky Clarke & Ruopeng An (2020) Effect of eccentric overload training on change of direction speed performance: A systematic review and meta-analysis, Journal of Sports Sciences, 38:22, 2579-2587, DOI: 10.1080/02640414.2020.1794247

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Section III – Sports Training

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Effects of Flywheel Resistance Training on Sport Actions. A Systematic Review and Meta-Analysis

Chronic effects of flywheel training on physical capacities in soccer players: a systematic review

William J.C. Allen, Kevin L. De Keijzer, Javier Raya-González, Daniel Castillo, Giuseppe Coratella & Marco Beato

To cite this article: William J.C. Allen, Kevin L. De Keijzer, Javier Raya-González, Daniel Castillo, Giuseppe Coratella & Marco Beato (2021): Chronic effects of flywheel training on physical capacities in soccer players: a systematic review, Research in Sports Medicine, DOI: 10.1080/15438627.2021.1958813

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Concentric and eccentric inertia–velocity and inertia–power relationships in the flywheel squat

Stuart A. McErlain-Naylor & Marco Beato

To cite this article: Stuart A. McErlain-Naylor & Marco Beato (2020): Concentric and eccentric inertia–velocity and inertia–power relationships in the flywheel squat, Journal of Sports Sciences, DOI: 10.1080/02640414.2020.1860472

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Validity and reliability of a flywheel squat test in sport

Marco Beato , Adam Fleming , Alexander Coates & Antonio Dello Iacono

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The Flywheel Paradigm in Team Sports: A Soccer Approach

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Implementing Flywheel (Isoinertial) Exercise in Strength Training: Current Evidence, Practical Recommendations, and Future Directions

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→ https://journals.lww.com/nsca-jscr/abstract/9000/effects_of_flywheel_vs__traditional_resistance.93858.aspx

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