APPENDIX A

Time Motion Analysis of Game Play

Time Period	Players						
	5 University (Forwards)[a]	3 University (Defensemen)[a]	10 University[b]	80 Junior[c]	170 Midget[c]	12 Old Timers[d]	89 Minor League[e]
Bench time between shifts (s)	293±16	189±18	225±25	329	147.5	276.3±14.0	228
Ice/shift time (s)				146.3	91.2	233.1	160
Bench/on-ice ratio	2.52	1.24	2.66	2.25	1.61	1.20	1.43
Playing time/game (s)	1152±54	1723±97	1471±84	1884	1032	1134	828
Shifts	20.2±0.6	24.3±0.7	17.4±1.0	12.8	11.3	7.8±0.6	9.0
Playing time/shift (s)	57.9±2.5	73.1±4.7	85.4±3.1	86.9		139.1±10.5	94.9
Total stoppage time/shift (s)	58.2	79.3	62.3	59.4		75.3±8.8	
Play stops/shift (s)	2.0±0.1	2.6±0.2	2.3±1.0			3.5±0.3	2.3
Time/play stoppage (s)	29.1±3.3	30.5±4.1	27.1±1.4			21.5	
Playing time between stoppage (s)	29.5±0.8	28.5±0.3	39.7±2.6			20.6±1.3	

[a] Data from Green *et al.* (1987a)
[b] Data from Green *et al.* (1976)
[c] Data from Léger (1980)
[d] Data from Montgomery & Vatzbedian (1979)
[e] Data from Paterson (1979)

(Montgomery, 1988)

APPENDIX B

Physical Characteristics of Ice-Hockey Players

Reference	Level of Play	Years of Experience	Age (yrs)	Stature (cm)	Mass (kg)	Body fat %
Houston & Green (1976)	Major Junior A & University League (ice-hockey)	Minimum of 8				
Forwards			19.1±2.2	176.2±5.0	77.9±6.2	10.2±2.9
Defense			18.7±1.8	180.8±5.3	82.2±7.3	10.1±2.4
Goalie			19.5±2.7	176.5±4.6	72.9±7.9	9.6±4.2
Smith *et al.* (1982)	Canadian Olympic Ice-Hockey Team (n=23)		19-29	179.8±1.1	81.1±1.3	10.6±0.1
Agre *et al.* (1988)	NHL (n=27)					
Goalies			25.0±3.0	177.2±2.8	77.7±3.2	8.7±2.4
Forwards			24.8±0.9	183.5±1.4	86.1±1.9	7.7±1.3
Defensemen			24.9±1.3	184.7±2.1	88.5±1.9	12.2±1.1
Twist & Rhodes (1993b)	NHL (n=31)					
Forwards			24.4±4.6	186.9±4.3	92.7±3.8	10.8±2.4
Defensemen			24.7±2.6	187.7±4.8	93.9±4.2	12.1±2.5
Goal tenders			27.3±4.5	184.2±3.1	84.1±4.6	13.5±3.1
Boyle *et al.* (1994)	Competitive Field Hockey Players (n=9)		26±4.5	177.3±3	75±5.4	12.4±2.4
Dreger & Quinney (1999)	Elite Ice-Hockey Players (n=6)		15.8±0.41	176.4±3.90	74.4±6.51	
Bracko (2001)	Elite Women's Ice-Hockey Players (n=8)	17±6	25±5	176.2±2.3	68.9±6.4	
	Non-elite Women's Ice-Hockey Players (n=15)	8±3	19±2	168.2±7.6	65.3±6.6	
Bracko & George (2001)	Women's Ice-Hockey Players (n=61)	4.68±2.69	12.18±2.05	153.05±14.38	44.41±12.30	18.37±5.5
Bracko & Fellingham (2001)	Calgary Hockey Players & American Hearing Impaired Hockey Association (n=19 female)	3.80±1.74	10.95±0.55	143.43±8.3	36.44±7.13	19±7.41
	Calgary Hockey Players & American Hearing Impaired Hockey Association (n=21 male)	5.0±0.89	10.75±0.65	140.92±4.11	35.66±4.32	7.58±2.24
	Calgary Hockey Players & American Hearing Impaired Hockey Association (n=20 female)	4.25±2.27	12.75±0.54	158.6±1.07	46.97±7.95	17.43±3.71
	Calgary Hockey Players & American Hearing Impaired Hockey Association (n=31 male)	6.68±1.06	12.25±0.52	159.17±8.68	48.28±8.54	6.80±3.41
	Calgary Hockey Players & American Hearing Impaired Hockey Association (n=15 female)	5.96±3.03	14.55±0.46	164.85±5.94	58.83±5.92	19.88±4.85
	Calgary Hockey Players & American Hearing Impaired Hockey Association (n=25 male)	9.0±1.63	14.65±0.26	166.69±9.99	56.92±9.61	13.8±2.96
Hoff *et al.* (2005)	Elite	10+	24.2±4.7	179.9±6.1	84.2±8.1	16.6±4.0
	Junior Elite	7	17.6±0.9	179±7	72.3±6.0	15.7±4.4
Behm *et al.* (2005)	Junior (n=30)	5-13	19.8±3.5	178.6±6.5	78.9±10.1	
Green *et al.* (2006)	National Collegiate (n=29)			182±5	84.9±6.4	12±3
Vescovi *et al.* (2006)	NHL Combines 2001 (n=74)		17.9±0.5	185.5±4.3	88.8±6.3	10.2±1.6
	NHL Combines 2002 (n=84)		18.0±0.6	185.3±4.5	87.5±6.1	10.0±1.5
	NHL Combines 2003 (n=92)		18.0±0.6	186.1±4.4	87.5±7.6	9.5±1.6

APPENDIX C

Muscular Endurance, Flexibility & Speed Characteristics of Ice-Hockey Players

Author	Level of Play	Yrs of Experience	Age (yrs)	Vertical Jump (cm)	Push-Ups (1 min)	Sit-Ups (1 min)	Sit & Reach (cm)	40 Yard Dash (s)
Bracko & Fellingham (2001)	Calgary hockey players & American Hearing Impaired Hockey Association (n=19 female)	3.80±1.74	10.95±0.55	29.76±6.63	28.94±12.62	32.5±8.0	39.6±7.82	7.45±0.61
	Calgary hockey players & American Hearing Impaired Hockey Association (n=21 male)	5.0±0.89	10.75±0.65	33.46±7.48	22.21±10.96	30.78±11.94	33.77±7.56	9.44±0.52
	Calgary hockey players & American Hearing Impaired Hockey Association (n=20 female)	4.25±2.27	12.75±0.54	31.0±7.2	31.95±10.65	35.15±7.5	37.39±9.99	7.01±0.5
	Calgary hockey players & American Hearing Impaired Hockey Association (n=31 male)	6.68±1.06	12.25±0.52	37.93±7.5	29.60±10.13	38.23±8.41	36.24±7.71	6.58±0.49
	Calgary hockey players & American Hearing Impaired Hockey Association (n=25 male)	9.0±1.63	14.65±0.26	44.43±8.14	37.44±11.55	42.72±7.11	39.28±8.75	6.40±0.42
Bracko (2001)	Elite Females (n=8)	7	25±5					
	Non-Elite Females (n=15)	3	19±2					
Bracko & George (2001)	Women's Ice-Hockey Players (n=61)	4.68±2.60	12.18±2.05	31.29±8.15	29.16±11.10	33.17±8.75	38.83±9.04	7.19±0.7
Hoff *et al.* (2005)	Elite	10+	24.2±4.7	48.2±4.6				
	Junior elite	7	17.6±0.9	43.6±3.6				
Vescovi *et al.* (2006)	NHL Combines 2001 (n=74)		17.9±0.5	67.2±8.3	Max 23.1±3.8	Max 39.6±22.8		
	NHL Combines 2002 (n=84)		18.0±0.6	58.8±6.1	Max 27.1±5.9	Max 23.5±12.9		
	NHL Combines 2003 (n=92)		18.0±0.6	56.1±9	Max 22.5±6.0	Max 16.5±10.5		

APPENDIX D

Aerobic & Anaerobic Capacity of Ice-Hockey Players

Reference	Level of Play	Age (yrs)	VO_2 max (ml kg^{-1} min^{-1})	VO_2 max Protocol	HR max	Anaerobic Lactate Capacity (mmol L^{-1})	Anaerobic Lactate Capacity Protocol	On-Ice Anaerobic Power (w kg^{-1})
Cunningham *et al.* (1976)	Highly Successful Competitive Players (n=15)	10.6±0.3	56.6±7.7	PWC_{170} (50 rpm, 5 min loads, 150 kpm for supramaximal)	197±8			
Houston & Green (1976)	Major Junior A & University League (n=48)	16-20 18-23	44.4-66.5	12.9 km h^{-1} 1% increase in grade every minute		7.2-21.7	12.9 km h^{-1} at 20% grade, La 5 & 12 min post test	
Smith *et al.* (1982)	Canadian Olympic Team (n=23)	19-29	54.0±1.2	Continuous Monark cycle protocol starting at 150 watts, increased by 0.5 Kp every 2 minutes				
Agre *et al.* (1988)	NHL (n=27)			Treadmill Bruce Protocol				
Goalies		25.0±3.0	53.1±1.2		192±3.7			
Forwards		24.8±0.9	54.2±1.3		186±2.1			
Defensemen		24.9±1.3	52.2±1.0		183±3.5			
Twist & Rhodes (1993b)	NHL (n=31)							
Forwards		24.4±4.6	57.4±3.1			15.1±2.1	Modified 30 s Wingate Cycle ergometre protocol	
Defensemen		24.7±2.6	54.8±3.9			14.9±1.8		
Goal tenders		27.3±4.5	49.1±2.5			14.9±2.2		
Dreger & Quinney (1999)		15.8±0.41	60.4±5.1	Skating treadmill (intermittent protocol, constant speed 14.4 -16.0 km h^{-1}; initial grade 0%, increasing by 2% every 2 min)	202.3±4.27			
			59.0±8.31	Cycle ergometre (5 min at 100-150 watt, increased by 25 watt every 2 min, 60 rpm)	200.7±4.55			
Bracko (2001)	Elite females (n=8)	25±5						6.63±0.42
Hoff *et al.* (2005)	Elite	24.2±4.7	57.4±4.7	Treadmill (inclination 6°), speed 6 km h^{-1} increased by 1 km h^{-1} every minute	191.1±4.3			5.5±0.27 (40 m)
	Junior Elite	17.6±0.9	58.5±4.4		203±9			
Green *et al.* (2006)	National Collegiate (n=29)		59±4	Discontinuous incremental treadmill (3 min stages, 90 s rest between stages; 9.7 km h^{-1} with 0% grade, 9.7 km h^{-1}, 5%, increasing by 1.6 km h^{-1} & 1%				
Vescovi *et al.* (2006)	NHL Combines 2001 (n=74)	17.9±0.5	58.9±3.5	Cycle ergometre (70 rpm, starting at 2.0 kp, increasing by 1 kp every 2 min for first 3 levels, there after by 0.5 kp every 1 min at 80 rpm)				
	NHL Combines 2002 (n=84)	18.0±0.6	55.9±5.7					
	NHL Combines 2003 (n=92)	18.0±0.6	57.7±5.2					

Reference	Group	n	Peak Power (W kg^{-1})	30-second Anaerobic Endurance (W kg^{-1})
Smith *et al.* (1982)	Canadian Olympic Forwards 1980	15	11.7±1.0	9.6±0.6
	Canadian Olympic Defense 1980	6	11.5±0.4	9.6±0.9
Rhodes *et al.* (1986)	NHL Defense	27	12.0±1.5	9.5±1.0
	NHL Forwards	40	12.0±1.2	9.1±5.5
	NHL Goal Tenders	8	11.4±1.1	8.6±5.2
Montgomery & Dallaire (1986)	Montreal Canadians- Defensemen	12	9.8±1.1	8.2±0.3
	Montreal Canadians- Forwards	6	10.3±0.4	8.7±0.7
	Montreal Canadians- Goaltenders	3	10.6±1.0	8.3±0.1
	Montreal Canadians 1981-82	27	9.9±0.7	8.3±0.3
	Montreal Canadians 1982-83	30	10.4±1.1	8.7±0.8
Watson & Sargeant (1986)	University and Junior	24	10.1±1.0	7.7±1.0
Gamble (1986)	University	17	11.5±0.6	9.2±0.5
Brayne (1985)	University	17	11.5±0.8	9.0±0.7

Montgomery (1988)

APPENDIX E

Physical Activity Readiness Questionnaire (PAR-Q)

(Canadian Society for Exercise Physiology)

Physical Activity Readiness
Questionnaire - PAR-Q
(revised 2002)

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

PAR-Q & YOU

(A Questionnaire for People Aged 15 to 69)

Regular physical activity is fun and healthy, and increasingly more people are starting to become more active every day. Being more active is very safe for most people. However, some people should check with their doctor before they start becoming much more physically active.

If you are planning to become much more physically active than you are now, start by answering the seven questions in the box below. If you are between the ages of 15 and 69, the PAR-Q will tell you if you should check with your doctor before you start. If you are over 69 years of age, and you are not used to being very active, check with your doctor.

Common sense is your best guide when you answer these questions. Please read the questions carefully and answer each one honestly: check YES or NO.

YES	NO		
☐	☐	1.	**Has your doctor ever said that you have a heart condition and that you should only do physical activity recommended by a doctor?**
☐	☐	2.	**Do you feel pain in your chest when you do physical activity?**
☐	☐	3.	**In the past month, have you had chest pain when you were not doing physical activity?**
☐	☐	4.	**Do you lose your balance because of dizziness or do you ever lose consciousness?**
☐	☐	5.	**Do you have a bone or joint problem (for example, back, knee or hip) that could be made worse by a change in your physical activity?**
☐	☐	6.	**Is your doctor currently prescribing drugs (for example, water pills) for your blood pressure or heart condition?**
☐	☐	7.	**Do you know of any other reason why you should not do physical activity?**

If you answered

YES to one or more questions

Talk with your doctor by phone or in person BEFORE you start becoming much more physically active or BEFORE you have a fitness appraisal. Tell your doctor about the PAR-Q and which questions you answered YES.

- You may be able to do any activity you want — as long as you start slowly and build up gradually. Or, you may need to restrict your activities to those which are safe for you. Talk with your doctor about the kinds of activities you wish to participate in and follow his/her advice.
- Find out which community programs are safe and helpful for you.

NO to all questions

If you answered NO honestly to all PAR-Q questions, you can be reasonably sure that you can:

- start becoming much more physically active – begin slowly and build up gradually. This is the safest and easiest way to go.
- take part in a fitness appraisal – this is an excellent way to determine your basic fitness so that you can plan the best way for you to live actively. It is also highly recommended that you have your blood pressure evaluated. If your reading is over 144/94, talk with your doctor before you start becoming much more physically active.

DELAY BECOMING MUCH MORE ACTIVE:

- if you are not feeling well because of a temporary illness such as a cold or a fever – wait until you feel better; or
- if you are or may be pregnant – talk to your doctor before you start becoming more active.

PLEASE NOTE: If your health changes so that you then answer YES to any of the above questions, tell your fitness or health professional. Ask whether you should change your physical activity plan.

Informed Use of the PAR-Q: The Canadian Society for Exercise Physiology, Health Canada, and their agents assume no liability for persons who undertake physical activity, and if in doubt after completing this questionnaire, consult your doctor prior to physical activity.

No changes permitted. You are encouraged to photocopy the PAR-Q but only if you use the entire form.

NOTE: If the PAR-Q is being given to a person before he or she participates in a physical activity program or a fitness appraisal, this section may be used for legal or administrative purposes.

"I have read, understood and completed this questionnaire. Any questions I had were answered to my full satisfaction."

NAME ____________________

SIGNATURE ____________________ DATE ____________________

SIGNATURE OF PARENT ____________________ WITNESS ____________________
or GUARDIAN (for participants under the age of majority)

Note: This physical activity clearance is valid for a maximum of 12 months from the date it is completed and becomes invalid if your condition changes so that you would answer YES to any of the seven questions.

Supported by: Health Canada Santé Canada

continued on other side...

Canada's **Physical Activity Guide** to Healthy Active Living

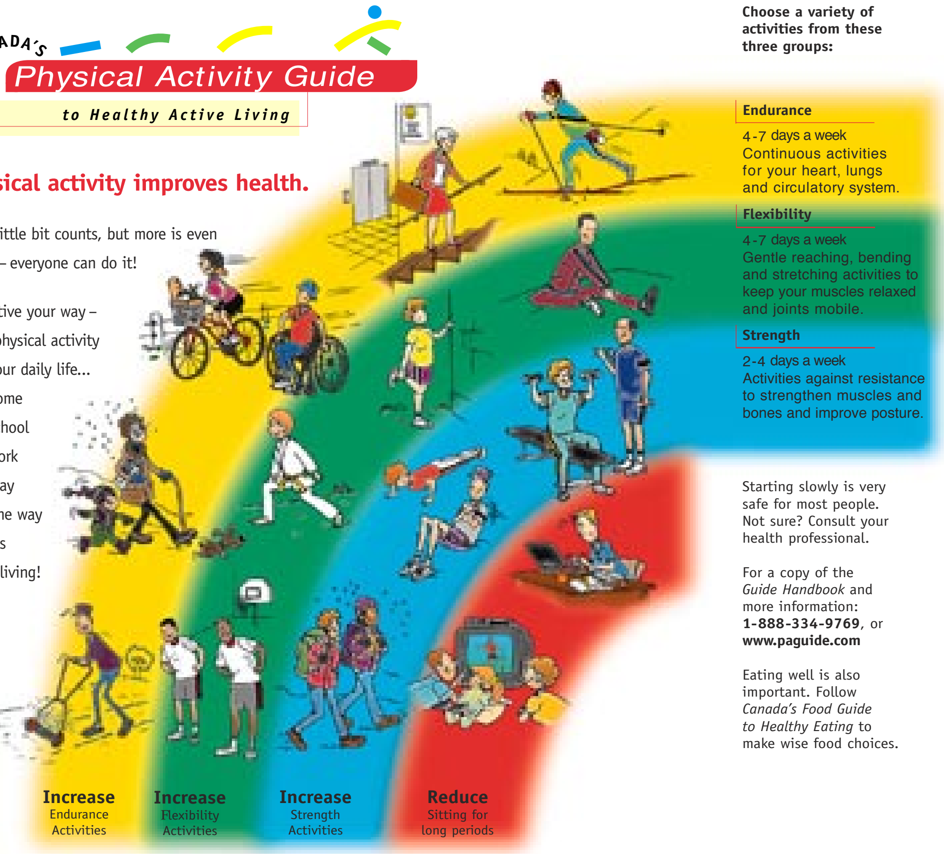
Physical activity improves health.

Every little bit counts, but more is even better – everyone can do it!

Get active your way – build physical activity into your daily life...

- at home
- at school
- at work
- at play
- on the way

...that's active living!



Starting slowly is very safe for most people. Not sure? Consult your health professional.

For a copy of the *Guide Handbook* and more information: **1-888-334-9769**, or **www.paguide.com**

Eating well is also important. Follow *Canada's Food Guide to Healthy Eating* to make wise food choices.

Get Active Your Way, Every Day – For Life!

Scientists say accumulate 60 minutes of physical activity every day to stay healthy or improve your health. As you progress to moderate activities you can cut down to 30 minutes, 4 days a week. Add-up your activities in periods of at least 10 minutes each. Start slowly… and build up.

Time needed depends on effort

Very Light Effort	Light Effort *60 minutes*	Moderate Effort *30-60 minutes*	Vigorous Effort *20-30 minutes*	Maximum Effort
• Strolling • Dusting	• Light walking • Volleyball • Easy gardening • Stretching	• Brisk walking • Biking • Raking leaves • Swimming • Dancing • Water aerobics	• Aerobics • Jogging • Hockey • Basketball • Fast swimming • Fast dancing	• Sprinting • Racing
	Range needed to stay healthy			

You Can Do It – Getting started is easier than you think

Physical activity doesn t have to be very hard. Build physical activities into your daily routine.

- Walk whenever you can – get off the bus early, use the stairs instead of the elevator.
- Reduce inactivity for long periods, like watching TV.
- Get up from the couch and stretch and bend for a few minutes every hour.
- Play actively with your kids.
- Choose to walk, wheel or cycle for short trips.
- Start with a 10 minute walk – gradually increase the time.
- Find out about walking and cycling paths nearby and use them.
- Observe a physical activity class to see if you want to try it.
- Try one class to start – you don t have to make a long-term commitment.
- Do the activities you are doing now, more often.

Benefits of regular activity:	Health risks of inactivity:
• better health • improved fitness • better posture and balance • better self-esteem • weight control • stronger muscles and bones • feeling more energetic • relaxation and reduced stress • continued independent living in later life	• premature death • heart disease • obesity • high blood pressure • adult-onset diabetes • osteoporosis • stroke • depression • colon cancer

Health Canada Santé Canada

Canadian Society for Exercise Physiology

ACTIVE LIVING

Cat. No. H39-429/1998-1E ISBN 0-662-86627-7

Canada's Physical Activity Guide to Healthy Active Living

Source: Canada's Physical Activity Guide to Healthy Active Living, Health Canada, 1998 http://www.hc-sc.gc.ca/hppb/paguide/pdf/guideEng.pdf

FITNESS AND HEALTH PROFESSIONALS MAY BE INTERESTED IN THE INFORMATION BELOW:

The following companion forms are available for doctors' use by contacting the Canadian Society for Exercise Physiology (address below):

The **Physical Activity Readiness Medical Examination (PARmed-X)** – to be used by doctors with people who answer YES to one or more questions on the PAR-Q.

The **Physical Activity Readiness Medical Examination for Pregnancy (PARmed-X for Pregnancy)** – to be used by doctors with pregnant patients who wish to become more active.

References:

Arraix, G.A., Wigle, D.T., Mao, Y. (1992). Risk Assessment of Physical Activity and Physical Fitness in the Canada Health Survey Follow-Up Study. **J. Clin. Epidemiol.** 45:4 419-428.

Mottola, M., Wolfe, L.A. (1994). Active Living and Pregnancy, In: A. Quinney, L. Gauvin, T. Wall (eds.), **Toward Active Living: Proceedings of the International Conference on Physical Activity, Fitness and Health**. Champaign, IL: Human Kinetics.

PAR-Q Validation Report, British Columbia Ministry of Health, 1978.

Thomas, S., Reading, J., Shephard, R.J. (1992). Revision of the Physical Activity Readiness Questionnaire (PAR-Q). **Can. J. Spt. Sci.** 17:4 338-345.

For more information, please contact the:

Canadian Society for Exercise Physiology
202-185 Somerset Street West
Ottawa, ON K2P 0J2
Tel. 1-877-651-3755 • FAX (613) 234-3565
Online: www.csep.ca

The original PAR-Q was developed by the British Columbia Ministry of Health. It has been revised by an Expert Advisory Committee of the Canadian Society for Exercise Physiology chaired by Dr. N. Gledhill (2002).

Disponible en français sous le titre «Questionnaire sur l'aptitude à l'activité physique - Q-AAP (revisé 2002)».

Supported by: Health Canada Santé Canada

APPENDIX F

Letters of Approval From University of Pretoria & University of Montréal Ethics Committees

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

Université de Montréal

Département de kinésiologie

Dossier No. 735

Montréal, le 26 septembre 2006

Monsieur Luc Léger
Professeur titulaire
Département de kinésiologie
CEPSUM, 2100 boul. Édouard-Montpetit
Bureau 7203

OBJET : Certificat d'éthique

Monsieur Léger,

Vous avez soumis le projet intitulé « Validité comparative de trois tests en patin à glace pour évaluer l'aptitude aérobie de hockeyeurs adultes » pour évaluation par le Comité d'éthique de la recherche des sciences de la santé (CÉRSS).

Je suis heureuse de vous informer que le Comité a jugé le projet conforme aux normes déontologiques. Un certificat d'éthique a donc été émis et vous est envoyé.

Le certificat d'éthique est émis pour une durée d'un an. À l'échéance, un suivi déontologique sera effectué, conformément aux normes de fonctionnement du Plan d'action ministériel en éthique de la recherche et en intégrité scientifique.

Il est aussi à souligner que vous devrez faire part au CÉRSS de toute nouvelle information (changement dans les connaissances scientifiques…) ou observation (événement négatif…) ou de tout changement au protocole expérimental, qui pourrait modifier le fondement éthique sur lequel repose votre projet de recherche.

Je vous prie de recevoir, Monsieur, l'expression de mes salutations distinguées.

Marie-France Daniel
Présidente
Comité d'éthique de la recherche des sciences de la santé
CEPSUM, 2100 Edouard-Montpetit, bureau 7211
Téléphone : (514) 343-5624
Télécopieur : (514) 343-2181
Courriel : marie-france.daniel@umontreal.ca

p.j.

Université de Montréal

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

Département de kinésiologie

DOSSIER No. 735

COMITÉ D'ÉTHIQUE DE LA RECHERCHE DES SCIENCES DE LA SANTÉ (CÉRSS)

CERTIFICAT D'ÉTHIQUE

Titre du projet : Validité comparative de trois tests en patin à glace pour évaluer l'aptitude aérobie de hockeyeurs adultes

Sous la direction de : Monsieur Luc Léger

Nom de l'étudiant : Madame Suzanne Kuisis

À la réunion du 28 août 2006, 11 membres du CÉRSS étaient présents : la présidente, la vice-présidente, l'experte en éthique, l'experte en droit, un représentant du public, la représentante des étudiants, le représentant de la Faculté de pharmacie, la représentante de la Faculté de médecine dentaire, la représentante de l'École d'optométrie, la représentante de la Faculté des sciences infirmières, le représentant du Département de kinésiologie.

Le Comité a jugé le projet mentionné ci-haut conforme aux règles d'éthique de la recherche sur les êtres humains.

Le certificat est émis pour la période du 26 septembre 2006 au 25 septembre 2007.

Le 26 septembre 2006.

Marie-France Daniel
Présidente
Comité d'éthique de la recherche des sciences de la santé
CEPSUM, 2100, Edouard-Montpetit, bureau 7211
Téléphone : (514) 343-5624
Télécopieur : (514) 343-2181
Courriel : marie-france.daniel@umontreal.ca

University of Pretoria

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

Research Proposal and Ethics Committee
Faculty of Humanities

31 January 2006

Dear Doctor van Heerden

Project:	***Validation and normative establishment of the modified (skating) 20 Metre Multi-stage Shuttle-run Test***
Researcher:	**SM Kuisis**
Supervisor:	**Dr HJ van Heerden**
Department:	**Biokinetics, Sport & Leisure Science**
Reference number:	**25519833**

Thank you for your correspondence of 7 December 2005 regarding the above application for ethical clearance.

I have pleasure in informing you that the Research Proposal and Ethics Committee formally approved the above study at an *ad hoc* meeting held on 26 January 2006. The approval is subject to the candidate abiding by the principles and parameters set out in her application and research proposal in the actual execution of the research.

The Committee requests you to convey this approval to Ms Kuisis.

We wish you success with the project.

Sincerely

Brenda Louw

Prof Brenda Louw
Chair: Research Proposal and Ethics Committee
Faculty of Humanities
UNIVERSITY OF PRETORIA

University of Montreal

Department of Kinesiology **Dossier No 735**

Montreal, 26 September 2006

Mr Luc Léger
Tenured Professor
Department of kinesiology
CEPSUM, 2100 boul. Edouard-Montpetit
Office 7203

RE: Ethics Certificate

Sir,

You submitted the project entitled "Comparative validity of three ice skating tests to evaluate the aerobic aptitude of adult hockey players" for assessment by the Ethics Committee of the Health Science Research Institute (CERSS).

I am glad to inform you that the committee considered that the project complied with deontological standards. Therefore, an ethics certificate has been issued and is being sent to you.

The ethics certificate is issued for a period of one year. At the end of the period, a deontological follow-up will be carried out, in accordance with the operating standards of the ministerial plan of action for research ethics and scientific integrity.

We wish also to emphasise that you will have to inform the CERSS of any new information (change in scientific knowledge…) or observation (negative event) or any change in the experimental procedure, which could modify the ethical basis on which your research project rests.

Yours faithfully

Marie-France Daniel
Chairlady
CERSS
CEPSUM, 2100 Edouard-Montpetit, office 7211
Tel. (514) 343-5624
Fax: (514) 343-2181
e-mail: marie-france.daniel@umontreal.ca

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UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

University of Montreal

Department of Kinesiology **Dossier No 735**

ETHICS COMMITTEE OF HEALTH SCIENCE RESEARCH (CERSS)

ETHICS CERTIFICATE

Title of the Project: Comparative validity of three ice skating tests to evaluate the aerobic aptitude of adult hockey players.

Under the direction of: Mr. Luc Léger

Name of student: Mrs Suzanne Kuisis

At the meeting of 28 August 2006, 11 members of the CERSS were present: the chairlady, the vice-chairlady, the ethics expert, the law expert, a representative of the public, a student representative, representatives of the faculty of pharmacy, a representative of the faculty of dental medicine, a representative of the optometry School, a representative of the faculty of nursing, a representative of the Department of kinesiology.

The committee considered that the above-mentioned project complied with the ethics rules of research on human beings.

The certificate is issued for the period from 26 September 2006 to 25th September 2007

26 of september 2006

Marie-France Daniel

APPENDIX G

Informed Consent

Please note that this document was originally in French (as all the subjects were French) and has been translated for examination purposes.

Voluntary consent Form
To take part in the study described below

TITLE OF STUDY:

COMPARATIVE VALIDITY OF THREE ICE SKATING TESTS TO EVALUATE THE AEROBIC APTITUDE OF ADULT HOCKEY PLAYERS

STUDENT RESEARCHER: **Suzan KUISIS**

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MAIN RESEARCHER: **Luc LEGER**...

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INTRODUCTION

Maximum oxygen consumption (VO_2 max) is a key parameter for performance in ice hockey. This is usually measured directly, in a laboratory where the subject is connected to a gas analyzer. Three new ice-skating tests to measure VO_2 max have recently been developed to make testing more specific to the sport, and that predict VO_2 max from the maximum speed reached during those tests that have progressively increasing speed. These new tests have been researched by different researchers on different groups of subjects. It is necessary to validate the new tests and to compare these new tests to determine the advantages and disadvantages of each test.

AIMS AND OBJECTIVES OF THE STUDY

The aims of this study are to:

1. assess the validity and suitability of three ice-skating tests and compare the three ice-hockey tests to determine their degree of concordance,
2. to compare these tests to the measurement of VO_2 max obtained on the treadmill in the laboratory, and
3. compare a conventional 20-m shuttle running test in a gymnasium with the hypothesis that such a simple test would be as valid as more specific ice skating tests that require costly ice time.

TERMS FOR PARTICIPATION IN THE STUDY

Each subject must therefore be available for 5 tests within a 2 to 3 week period. The tests take place in a mixed order according to the first test the subject takes, in order to avoid any bias. No more than one test per day and no more than 3 tests on consecutive days will be performed as this will affect the results. The tests will consume approximately 2 hours of your time. The tests will take place at the Human Performance laboratory, gymnasium, and the ice arena at CEPSUM (university of Montreal). Tests will be conducted by the student researcher, Suzan Kuisis, who will be assisted by students.

DESCRIPTION OF THE TESTS

STANDARD TEST ON TREADMILL

The treadmill test will be done in the Human Performance Laboratory of the Department of Kinesiology, at the University of Montréal also located in the CEPSUM. The maximum standard treadmill test with multiple stages will be approximately 10 to 20 minutes in duration according to each subject's physical aptitude. This test begins at 10 km h^{-1} (slow speed, easy for everyone); the speed increases with 1 km h^{-1} after each 2 min stage. A nose clip will be worn and a mouthpiece is held in the mouth. During this test, the subject will be connected to a gas analyzer, the subject breathes through the mouthpiece, which containing a valve which directs the ambient air into the mouth at the time of the inspiration and the air expired into the system for means of analysis and calculation of the oxygen uptake (VO_2), a measure of the expenditure of energy. The mouthpiece and the valve are maintained in place by means of an adjustable headset. The subject also wears a nose-clip. Besides the slight discomfort, this system does not present any risk for the subject. The VO_2 measured within the last stage represents the maximum oxygen consumption of the subject (VO_2 max). This measurement of the aerobic aptitude is used as standard measurement to validate the field tests, in gymnasium and on ice.

FIELD TESTS IN THE GYMNASIUM AND ON ICE

Each subject must also do 4 other field tests, in a gymnasium (1x) or on ice with skates (3x). These tests are carried out in groups of 3 to 6 subjects. The duration of these tests is 10 to 20 minutes, but will depend on the physical aptitude of each subject. Each test is maximal and progressive, and is easier at the start and becomes more difficult. Subjects are required to give a maximal effort. Subjects will need to allow time for changing into fill hockey kit and for a 5 minute explanation of each test.

The principle characteristics of each of the field tests are described in Table 1 below and shown in Figure 1.

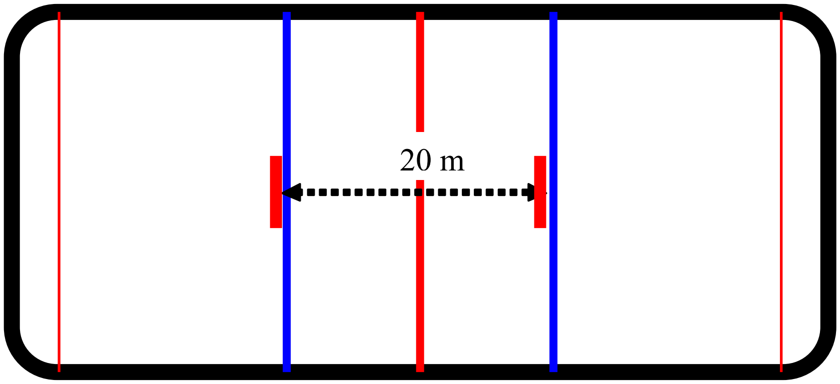
Table 1. Characteristics of the maximal multistage running and ice skating tests.

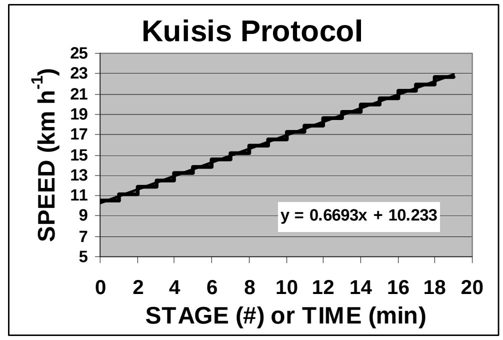
	20-m shuttle run	**20-m shuttle skate**	**45-m shuttle skate**	**48.8 m shuttle skate**
Source	Léger al 1988	Kuisis 2001	Leone al 2006	Petrella 2006
Displacement technique	Shuttle Stop & Go Gym Running	Shuttle Stop & Go Ice Skating 1 hand on stick	Shuttle Stop & Go Ice Skating 1 hand on stick	Shuttle Wide turn Ice Skating 1 hand on stick
Protocol Type	Max Multistage Continuous	Max Multistage Continuous	Max Multistage Intermittent	Max Multistage Continuous
Speed vs Stage	Linear	Linear	Linear	Curvilinear
Stage duration	1 min	1 min	1 min	45 s → 19.5 s*
Rest interval	0 s	0 s	30 s	0 s
Initial speed	8. 5 km h^{-1}	10.0 km h^{-1}	12.6 km h^{-1}	15 s (11.7 km h^{-1})
Speed increase	0. 5 km h^{-1}	0. 5 km h^{-1}	0.72 km h^{-1}	-5 s (0.4→2.0 km h^{-1})
Equipment	Running shoes	Full hockey gear (+ portable VO_2 system**)	Full hockey gear	Skates, Stick, helmet, gloves

* For the best results so far

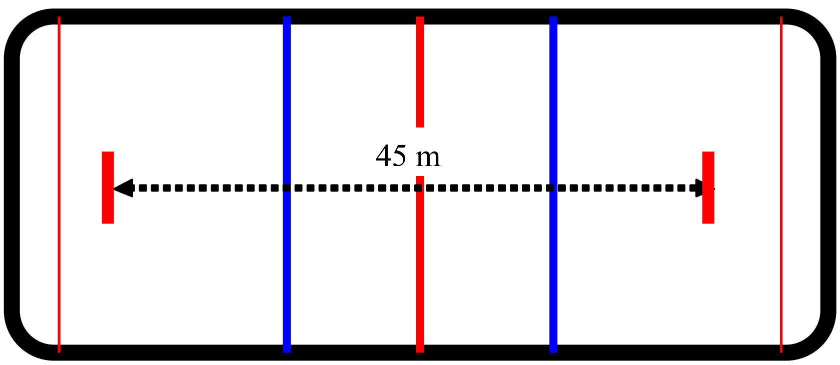
Figure 1. Ice-skating tests

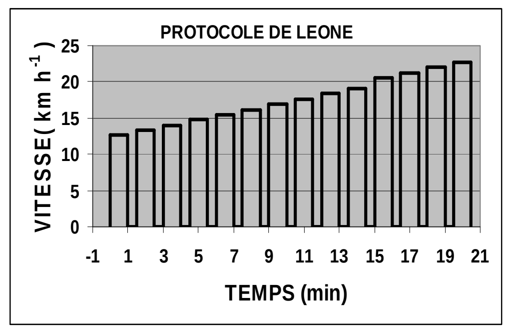
1. **Kuisis 2001 Test**



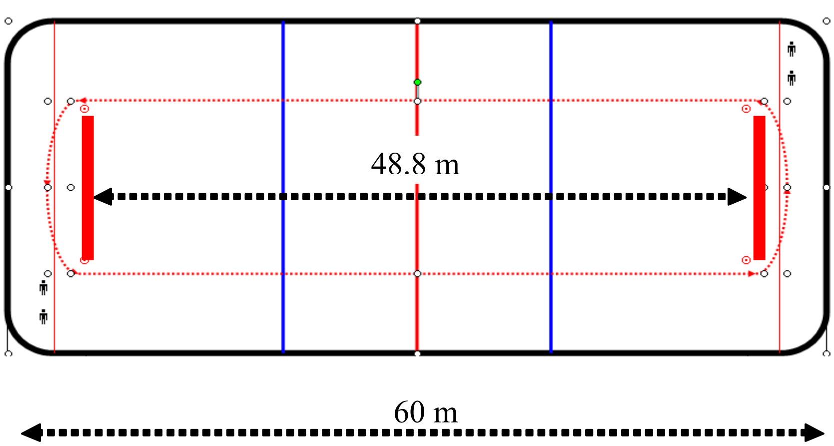


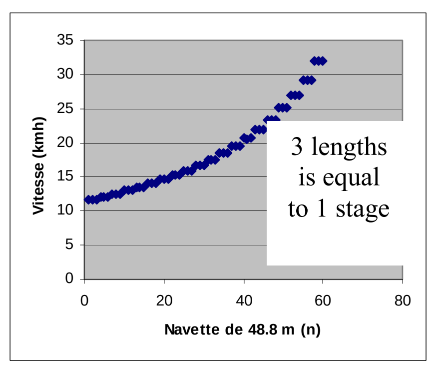
2. **Leone Test**





3. **Faught Test**





MEASUREMENTS TAKEN DURING THE TESTS

1. The performance score of the test is the number of completed stages
2. VO_2 will be measured continuously during the standard treadmill test. The maximum value reached at the end of the test (VO_2 max) is used as the standard to validate the maximum speed reached at the end of the field tests. The VO_2 is measured by the collection of gases expired during the treadmill test, as described in the preceding section
3. Measurement of blood lactate will be used as an indication of the overall intensity of the tests, indicating the gross anaerobic contribution of the test. Lactate will be measured by pricking the finger and collecting a drop of blood, between 5 and 8 minutes of completion of each test. This procedure is similar to that used by people who monitor their blood glucose by means of a domestic glucose meter. The prick is a little painful, but it is without danger if one takes the precautions (sterilization)
4. Measurement of maximal HR at the end of each test to determine the respective intensity or difficulty of each test
5. The Borg Rated Perceived Exertion (RPE) is also used to establish the degree of difficulty of each test, and is subjectively established on a 6 to 20 point scale from "very very easy" to "very very difficult" and constitutes another classical indication of the overall difficulty of each test. This only takes a few seconds
6. Likert resemblance score is obtained on a subjective scale. Each test will be evaluated at 5 levels (questions), on a scale of 1 to 7 where subjects rate the similarity of the test to ice-hockey and the suitability of the test to evaluate aerobic fitness in ice-hockey players. This takes less than one minute to answer
7. During the tests on ice, the subjects will be filmed in order to try to develop indices of the level of skill and technique of stopping, starting, the skating of crossovers and turns. The technical level could then be used, with maximum speed, as a determinant in the prediction of VO_2 max.

CONDITIONS OF PARTICIPATION

Inclusion criteria

1. healthy males aged between 18 and 50 years of age,
2. hockey players who have mastered their skating skills (start, stop, forward acceleration, skating turns and cross-overs)
3. be available for the duration of the study and to come to the University for all 5 testing sessions
4. read, understand and voluntarily sign an informed consent form describing the tests to be done

Exclusion criteria

1. failure to meet inclusion criteria just described
2. having a medical contraindication to exercise from his medical doctor or answer yes to any of the questions in the PAR-Q physical readiness questionnaire of the Canadian Society for Exercise Physiology
3. injury during the testing period

ADVANTAGES IN PARTICIPATING

The evaluation of an athlete's physical aptitude, whatever his speciality, forms part of the planning process of sport training The evaluation of physical aptitude in athletes is a specialized process. By participating in this project you will obtain results regarding your aerobic capacity, which constitutes an important aspect of performance. We will also be able to discuss with you the strategies which are available to you to improve this parameter.

RISKS AND DISCOMFORT

In the course of those physical tests, you my experience great fatigue. All precautions are taken to ensure that the tests take place in the safest manner possible. The laboratory is equipped with an automated external defibrillator and researchers have obtained cardiopulmonary resuscitation certificates (the Head of the laboratory is also a certified CPR instructor, Arthur Long, 343 6111, extension 4238).

The PAR-Q questionnaire helps to minimize the risk of your participation, and eliminate subjects who are potentially at risk. The PAR-Q comprises a margin of error and the risks detected by the PAR-Q require confirmation by a doctor.

VOLUNTARY PARTICIPATION AND WITHDRAWL OR EXCLUSION FROM THE STUDY

Your participation is completely voluntary. You have a 48 h delay after: 1) you have filled in the PAR-Q, 2) acquainted yourself with the consent form, and 3) asked for additional explanations from the researcher and confirm your participation in the study, in order to give you time to ask for advice of a third party if need be.

If you wish to be included in the study, we will then ask you for your written consent by signing this form. If you no longer wish to participate, you are free to withdraw at anytime without prejudice and without having to justify your decision. If necessary, you must notify one of the two principal researchers identified at the beginning of this form.

You will be advised of all new information likely to make you reconsider your participation in the study.

COMPENSATION IN THE CASE OF HARM

The University of Montréal is required by law to compensate for prejudices/ injuries which may have been caused by your taking part in this study.

CONFIDENTIALITY OF INFORMATION

All the data and information concerning subjects will remain STRICTLY CONFIDENTIAL and will be saved in individual files identified by a rank number corresponding to the first test taken by all the subjects (from 1 to 30 in the order of inclusion), and subjects real identification will be kept in a separate file kept in another secure place accessible to the researchers only. Individual files will be stored for 7 years after the study to be destroyed thereafter.

The results can be obtained only from the principal researchers or the associated researchers, who are Suzan Kuisis, doctoral student responsible for the project (University of Pretoria, South Africa) and Luc Leger, professor responsible for supervising the project (University of Montreal). Authorized representatives of the ‘research institutions, government agencies or ethics committees can possibly ask to examine the personal data for ethical review or follow-up. The original data will be preserved in South Africa but the principal researcher also preserves an electronic copy of the captured data.

QUESTIONS ON THE STUDY (INFORMATION & EMERGENCY)

If you have any questions regarding the study, please communicate with the researchers:

Suzan KUISIS	suzan.kuisis@up.ac.za	Tel: +1 (514)343 6111 Extension 3125
Luc LEGER	luc.leger@umontreal.ca	Tel: +1 (514)343 7792

ETHICS

If you have any ethical problems or concerning the conditions of your participation this study, you can discuss it with the person responsible for the project, or explain your concerns to the president of the Ethical Council of Health Science Research, Marie-France Daniel, telephone (514) 343-5624.

After following this procedure, if you had serious reasons to believe that the answer brought is insufficient, you could enter into communication with the officials of the University, Mrs Marie-José Rivest (telephone (514) 343-2100).

SIGNATURES

TITLE OF STUDY:
COMPARATIVE VALIDITY OF THREE ICE SKATING TESTS TO EVALUATE THE AEROBIC APTITUDE OF ADULT HOCKEY PLAYERS

MAIN RESEARCHER OR RESEARCHER RESPONSIBLE FOR THE STUDY :
(name in well formed letters):

..

I, (name of the participant in well-formed letters)..
declare that I acquainted myself with the attached documents of which I received a copy, that I discussed it with (name of the investigator in well-formed letters......................
and that I understand the aim, nature, advantages, risks and disadvantages of the study in question.

After some thought and a reasonable period of time, I freely consent to take part in this study. I know that I can withdraw at any time without any prejudice.

Signature of the participant................................. Date ....
Signature of the parent if you are under 18 years of age
___________________________Date____________

I, (name of the investigator in well-formed letters) ....
declare that I explained the aim, nature, advantages, risks and disadvantages of the study to (name of participant in well-formed letters)...

Signature of the investigator .... Date ....

APPENDIX H

Order of Testing

Order of Testing					
	Treadmill	Skating 20 MST	SMAT	FAST	Running 20 MST
Subject no.					
1	1	2		3	
2	1	2			
3	1	2			
5	1	4	3	2	5
6	1	3	4	2	5
7	3	2	5	1	4
8	3	1	2	4	5
9				1	
10	3	1	5	2	4
11	2		1	3	4
12		1	2	3	
13	4	3	1	2	5
14	4	2	1	3	5
15	4	1	3	2	5
16	4	2	1	3	5
17	5	2	1	3	4
19	3	2	1	4	
20		1			
21	4	3	1	2	5
22	4	1	2	3	5
23	4	1	3	2	5
24	4	2	1	3	5
25	4	3	1	2	5
26	4	1	3	2	5
27	2		1	3	
28		3	2	1	
29	1	3	4	2	

APPENDIX I

Raw Data Collection Sheet

Subject information

Subject Name & Surname					
Date of birth					
Age (yrs)					
Position					
Right/ left shoot					
Years of hockey experience					
Level of best play & age					
Height (cm)					
Weight (kg)					
Date of Test					
Borg RPE (6-20)					
Likert Scale (1-7)	**Q1**	**Q2**	**Q3**	**Q4**	**Q5**
Treadmill					
Kuisis					
Leone					
FAST					
Runnng 20 MST					
La (mmol L^{-1}; 5 min post test)					
Heart rate data					
Order of testing →					
	Treadmill	**Kuisis**	**Leone**	**FAST**	**Running 20 MST**
Stage 1					
Stage 2					
Stage 3					
Stage 4					
Stage 5					
Stage 6					
Stage 7					
Stage 8					
Stage 9					
Stage 10					
Stage 11					
Stage 12					
Stage 13					
Stage 14					
Stage 15					
Stage 16					
Stage 17					
Stage 18					
Stage 19					
Stage 20					
Final speed (km h^{-1})					
VO_2 max (ml kg^{-1} min^{-1})					
Test duration					
Temperature (˚C)					
Humidity (%)					
Barometric pressure (mmHg)					

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APPENDIX J

Borg Rating of Perceived Exertion Scale

Borg Scale

Rating of Perceived Exertion

6	
7	Very, very light/ Très, très facile
8	
9	Very light/ Très facile
10	
11	Fairly light/ Assez facile
12	
13	Somewhat hard/ Assez difficile
14	
15	Hard/ Difficile
16	
17	Very hard/ Très difficile
18	
19	Very, very hard/ Très, très difficile
20	

APPENDIX K

Likert Scale

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Likert scale

Q1 Similarity of basic skating skills (not puck handling) of test compared to those of a hockey game

LOW → **HIGH**

1 2 3 4 5 6 7

Q2 Resemblance between the maximal intensity of the test & maximal intensity of a hockey game

LOW → **HIGH**

1 2 3 4 5 6 7

Q3 How is the test suited to evaluate aerobic fitness of hockey players

LOW → **HIGH**

1 2 3 4 5 6 7

Q4 How is the test suited to evaluate overall fitness (including muscular and cardiovascular fitness) of hockey players

LOW → **HIGH**

1 2 3 4 5 6 7

Q5 How is the test suited to evaluate overall hockey ability (fitness and technical (skating) skills) of hockey players

LOW → **HIGH**

1 2 3 4 5 6 7

Validity of 3 ice skating aerobic field tests for hockey players.

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Abstract

Three aerobic maximal multistage ice skating tests have recently been introduced: 1) MS20MST, a continuous 20 m stop-and-go; 2) SMAT, an intermittent 45 m stop-and-go; and 3) FAST, a continuous 48.8 m shuttle with wide turns. In a paired design, the aim was to compare MS20MST, SMAT, and FAST to each other and to treadmill VO_2max and to the 20 m gym aerobic shuttle run (20 MST) in order to assess the relative validity of these tests to predict maximal aerobic power (VO_2max), to determine which test is best suited to do so and best rated by subjects, and to determine if these on-ice skating tests are any better than the over-ground 20 MST in 25 adult ice hockey players. Similitude with the intensity of hockey game and suitability as an aerobic test for ice-hockey was determined with a subjective 7-point Likert resemblance scale. FAST showed the lowest ($p<0.05$) Borg RPE, maximal lactate, HRmax, and ratings on the Likert Scale. Compared to treadmill VO_2max, correlations were 0.74, 0.73, 0.41 and 0.84 for MS20MST, SMAT, FAST and the 20 MST, respectively, and 0.75, 0.78, 0.53 and 0.94, respectively with maximal treadmill speed. FAST is less valid than MS20MST and SMAT, and it's lower HR max and LA max values do not support that test. Correlations between MS20MST, SMAT and 20 MST were approximately 0.7 but lower between these tests and FAST (approximately 0.4). MS20MST or SMAT protocols should be used if ice time is available, alternatively the gym 20 MST.

Keywords: Aerobic power, Skating, Ice-hockey, Modified Skating 20 MST, SMAT, FAST, test, validity, shuttle

Introduction

Maximal aerobic power is a key parameter for sport performance even for a highly anaerobic and high-speed intermittent sport such as ice hockey (Montgomery, 2006). VO_2max values are also specific to the muscles used and the type of activity used by subjects in their training regimen (Léger *et al.*, 1980, Mc Ardle *et al.*, 1978), and demonstrated that as compared to runners, ice-hockey players had a 15% greater mechanical efficiency while skating on the ice and a 7.9% lower mechanical efficiency on the treadmill (Léger, Seliger & Bassard, 1979). Sport specific tests are thus highly valued and have been applied in many sports such as endurance running (Léger & Boucher, 1980), intermittent running sports such as soccer and basketball (Léger *et al.*, 1988), cross-country skiing (Doyon *et al.,* 2001; Vergès *et al.*, 2006), badminton (Chin *et al.,* 1995), cycling (Ricci & Léger, 1983; Marion & Léger, 1988), swimming (Lavoie *et al.*, 1985; Monpetit *et al.,* 1981), water polo (Rechichi *et al.,* 2000), and soccer (Nicholas, Nuttall & Williams*,* 2000; Labsy *et al.,* 2004).

In an attempt to make laboratory testing more specific to ice-hockey, Montgomery's group from McGill University in Montreal (Nobles *et al.* 2003) developed a skating treadmill protocol. The skating treadmill is more "skating specific" than running or cycling, because it mimics the skating movement and solicits same muscle groups; it is also easier to control the speed and distance on a skating treadmill (vs. ice field tests). However the skating treadmill has many disadvantages (grade skating alters the mechanics of skating and increases resistance, low accessibility, high cost, individual testing and non-competitive environment, lack of wind resistance, and higher temperature).

Recently three new skating tests to assess aerobic fitness have emerged, namely the Skating Multistage Aerobic Test (SMAT, Leone *et al.,* 2007), the Modified Skating 20 MST (MS20MST, Kuisis, 2003), and the Faught Aerobic Skating Test (FAST, Petrella *et al.,* 2007). The validity of these three ice-skating field tests is, however, not always obvious since the reported statistical indices (r and SEE) are quite different, probably because they were obtained for different age and gender groups, sometimes with small groups of subjects, wearing different equipment, and using different types of protocols. Among the newly introduced tests, required skating ability and skills are different. Direction changes in the MS20MST and SMAT rely on stop-and-go while FAST requires a wide turn and cross-over skating. Thus with a paired design, the aim of the study was to compare MS20MST, SMAT, and FAST to each other and to a treadmill VO_2max criterion in order to determine the best aerobic skating test; to determine which test is rated by the players as being the best suited and most functional test, and finally to compare each test to the 20 MST (Léger *et al.,* 1988) to determine if these on ice skating tests are any better than the over-ground 20 MST that does not require costly ice time.

Materials and methods

Subjects and experimental protocols

Adult male ice-hockey players (n=26) of various fitness and ice-hockey levels gave their informed consent to participate in the study approved by the ethics committee of the university approximately six weeks before the start of the ice-hockey competitive season.

Only 16 subjects were able to free themselves to complete all five tests (Table 1). All testing facilities, Human Performance Laboratory, Indoor track and Ice arena (55 m x 26 m), were located in the university fitness center (CEPSUM, University of Montreal). Subjects performed five maximal multistage aerobic tests on separate days, and were not permitted to participate in more than one test per day on any two consecutive days, where after a minimum period of 24 hours rest was required before the next test. All five tests were however completed within three weeks. Due to the fact that there were up to four subjects participating in the field tests at the same time, test order could not be totally randomized. However, test order was mixed as much as possible to avoid any systematic ordering of the tests. All ice-tests were done on resurfaced ice. Field tests are detailed in Table 2.

Warm-up before running tests (treadmill and 20 MST) consisted of four to five minutes low intensity jogging (6-8 km h^{-1}), followed by five minutes of stretching. Upon completing the running tests, subjects recovered actively for four to five minutes by walking. Warm-up procedures for all ice protocols (MS20MST, SMAT and FAST) consisted of five minutes of submaximal skating around the outer perimeter of the ice (alternating direction), followed by a few easy stop and go drills, for the MS20MST and SMAT. Finally four to five minutes of stretching was performed. Upon completing the skating tests, subjects recovered actively for four to five minutes by skating slowly and gliding around the ice. Before any of the field tests were begun, the compact disc of the specific test was played, consisting of a brief explanation of the test, leading to a countdown of the start. Set-up, procedures, and termination criteria were used as specified by the respective authors.

Dependent variables and methods

Heart rate (HR)

HR was continuously measured with a Polar pulse monitor (Polar Electro, Kempele, Finland). Submaximal HR values were recorded at 15 s intervals. Maximal HR value was recorded at the end of each test as an indication of the overall difficulty or intensity of each test.

Blood lactate

A Lactate Pro (Arkray, Inc, Kyoto, Japan) was used to assess finger prick (capillary) lactate between five and eight minutes of recovery. Blood lactate was considered another indication of the overall intensity of the tests, indicating the gross anaerobic contribution of the test.

Borg Rate of Perceived Exertion Scale (RPE)

The Borg Rated Perceived Exertion (RPE) (Borg, 1970) was subjectively established on a 6 to 20 point scale for every test upon termination of the test to determine the final perceived intensity of the tests.

Likert Resemblance Scale

A resemblance score was obtained on a subjective seven point Likert (1932) scale (one being the lowest possible score and seven being the highest possible score, for all questions, the higher the score, the better the result, indicating, for example, greater similarity between the test and an ice-hockey game or greater suitability of the tests to assess aerobic fitness in adult ice-hockey players); after the completion of each test. Each of the tests performed by the subjects was evaluated at five levels:

1. the similarity of the technical skating skills (excluding stick/puck handling) of the test with those of the hockey game,
2. the resemblance between the maximal intensity of the test and maximal intensity of the hockey game,
3. how the test is suited to evaluate aerobic fitness of the hockey players,
4. how the test is suited to evaluate overall fitness (including cardiovascular and muscular fatigue) of the hockey players, and
5. how the test is suited to evaluate overall hockey ability (fitness and technical skating skills) of the hockey players

VO_2max

VO_2 was measured every 30 s with the open circuit method (Moxus Modular VO_2 system, AEI Technologies, Pittsburgh, Etats-Unis) during the laboratory treadmill running test. The VO_2 system was calibrated with standard reference gases and for volume approximately five minutes prior to each treadmill test. VO_2 values were recorded every 30 s. This protocol was a continuous multistage test with initial speed set at 10 $km \cdot h^{-1}$ with 1 km h^{-1} increment per stage (two minutes) thereafter. The subject ran until volitional exhaustion, and the highest VO_2 achieved (VO_2 peak) was considered VO_2max. VO_2max values for field tests were also estimated using original regression equation (Table 2)

Statistical analysis

Statistical analyses were performed using Statistica software (6th Edition, www.statsoft.com). Descriptive statistics (mean ± SD) were conducted for all variables. Multiple regression analysis was employed to construct an equation to predict VO_2max from the MS20MST using direct VO_2max from the treadmill test as the dependant variable and maximal MS20MST speed, height and weight, as the independent variables. Comparisons of maximal values of different variables (VO_2max, HR_{max}, Speed max, $Lactate_{max}$, test duration, Borg RPE max, and Likert scores) were done with a repeated one-way ANOVA to assess similarity in physiological difficulty of each test on the 16 subjects that completed all the tests. A posteriori test (Tukey) was used to determine exactly where the differences existed. Pearson correlation coefficients were also estimated for each variable in every test. Regression analysis (scatter plot, Pearson correlation and SEE) were applied between direct treadmill VO_2max and maximal speed for each of the four tests to establish predictive model, to determine the external validity and to compare validity of each field test in a pairwise design (n=16 to 23).

Another purpose was to establish pairwise equivalence between field tests. Since conventional regression analysis assumes that one variable is independent and the other, dependent, which is not the case when you compare two different field tests and, since, two non algebraically equivalent regressions are obtained depending on the subjective choice of the dependent variable, another approach was taken which would yield a bisectrix regression in the middle of the two others (Andersen et al., 1986). It is like considering perpendicular least squares to the regression line, instead of vertical ones. To get that regression, the slope b of the conventional regression has to be divided by the r value (new slope b = conventional slope / r) and to obtain the new intercept a, the average values of X and Y, have to be entered in the equation (Y = a + b X) using new slope b. SEE was obtained using predicted value of that non conventional regression model: $SEE = \sqrt{((\sum(Y_{observed}-Y_{predicted})^2)/(n-2))}$.

Results

VO_2max prediction from MS20MST.

Among potential and pertinent predictors of VO_2max such as MS20MST maximal speed, weight and height, only the MS20MST maximal speed (X, km h^{-1}) was retained by the stepwise multiple regression as a significant predictor of VO_2max (Y, ml kg min^{-1}):

Y = -33.337 + 6.24 X, r = 0.74, SEE = 5.93 (11.2%), n = 21 **EQ-1**

ANOVA comparisons between tests for each variable.

Anova and a posteriori Tukey tests revealed significant differences between tests (Figures 1 and 2). Maximal speed was progressively higher from the MS20MST, SMAT and FAST (13.7, 17.9, 20.3 km h^{-1}, $p<0.01$). Concerning duration of on-ice skating tests, it increased from MS20MST, to FAST, and to SMAT (5.62, 8.03 and 11.73 min, $p<0.01$). Maximal HR was higher during the treadmill test than during FAST (189.9 and 183.4 bpm, $p\leq0.01$) and also higher during SMAT than FAST (189.1 and 175.8, $p\leq0.05$). No other maximal HR difference was observed. Using the 6 to 20 RPE Borg scale, FAST was also subjectively perceived to be less difficult than any of the other four tests (15.1 vs. 16.9 and above, $p \leq 0.05$). With regards to maximal lactate, SMAT was higher than treadmill, FAST and 20 MST lactate (12.0, 9.3,10.2 mM respectively, $p \leq 0.001$) and MS20MST lactate higher than FAST lactate (11.33 and 9.19 mM, $p \leq 0.05$).

The predicted 20 MST VO_2max was significantly lower than the other tests except for the SMAT (48.4 vs. 51.8 to 54.0ml kg^{-1} min^{-1}, $p<0.05$, Figure 1).

Subjective ratings among the five tests are shown in Figure 2. When subjects rated the similarity of the skating skills (Q1) required by the test as compared to those required during a hockey game (excluding puck handling), both running tests yielded lower ratings than the three ice skating tests. And within the 3 ice skating tests, FAST scores were lower than MS20MST scores. MS20MST and SMAT are the best tests to mimic skating skill.

With regard to the similarity of the intensity of the tests to the game of ice-hockey (Q2), MS20MST and SMAT are again the best with treadmill and FAST as the worst and 20MST in the middle ($p<0.05$).

When tests were rated according to their suitability to evaluate aerobic fitness (Q3), and with regard to the suitability to evaluate overall fitness (Q4), FAST is trailing again with the lowest score while only being significantly lower than SMAT.

Lastly, with regard to suitability of the test to evaluate overall hockey ability (fitness and skating skills), treadmill and 20MST yield lower scores than the three skating tests while the skating tests were not significantly different from each other

Correlation and standard error of the estimate between each field test and the treadmill criterion test.

Results of criterion treadmill test could be expressed in VO_2max units (ml kg^{-1} min^{-1}) or maximal speed units (km h^{-1}). In general, correlations between maximal speed attained in field tests with criterion treadmill test are slightly better when results of the treadmill test are in speed units (Table 3). For example, for the 20MST, correlation was 0.84 with VO_2max units and 0.94 with speed units. That being said, ranking the tests according to their correlation yielded the same pattern whether VO_2max or maximal speed units are used. Using VO_2max units for example, we can see that FAST test is much less correlated with the treadmill test (r=0.41 with a SEE or 7.53 ml O_2 kg^{-1} min^{-1} or 14.7% of treadmill VO_2max mean) than the two other skating tests, MS20MST and SMAT (r=0.74 and 0.73 with SEE=5.93 and 5.65 ml kg^{-1} min^{-1} or 11.2 and 11 %, respectively). With an r value of 0.84 and SEE of 4.69 ml kg^{-1} min^{-1} or 9.02%, the running gym test, 20MST, is the best field test, assuming treadmill VO_2max is a proper criterion. Finally, the maximal speed attained on the treadmill compared to VO_2max obtained during the same test yielded a correlation of 0.84 with a SEE of 4.72 ml kg^{-1} min^{-1} or 8.95%. These r and SEE values were obtained using the maximum number of subjects for each comparison (n=17 to 23) but almost the same r and SEE values were obtained using only data from the same 16 subjects that did all the tests.

Scatterplots of the treadmill test as a function of each one of the three ice skating tests clearly demonstrates that to achieve the same aerobic fitness level on the treadmill, one has to skate at high speed in the FAST, medium speed in the SMAT and low speed in the MS20MST. (Figure 3).

Inter-correlations between field tests.

Table 4 reports correlations and SEE values between maximal speeds attained in each of the four field tests. Only two ice skating tests, MS20MST and SMAT, compare well to each other (r=0.84 and SEE=0.50 or 0.58 km h^{-1} depending on which test is considered as the dependent variable). The FAST is much less related to the two other ice skating tests (r=0.58 or 0.61 for MS20MST and SMAT respectively with SEE up to 1.89 km h^{-1} or 9.25%). Even the 20MST, a running gym test, is better correlated to the two other ice skating tests (r=0.83 and 0.87 for MS20MST and SMAT, respectively. with SEE less than 0.73 km h^{-1} or 5.83%). Equivalence regression coefficients are given in Table 4.

Discussion

Random error of field tests.

One purpose of this study was to establish a regression for the adaptation of 20MST, a gym shuttle run test, for an on-ice application, the MS20MST. EQ-1 indicates good accuracy (r=0.74 and SEE=5.93 ml kg^{-1} min^{-1} or 11.2%). This is slightly lower accuracy than the one obtained between treadmill VO_2max and maximal speed attained during the same treadmill test (r=0.838, SEE =4.72 ml kg^{-1} min^{-1} or 8.95%). Treadmill VO_2max was considered the criterion test because of its universal use and because similar VO_2 are obtained on the treadmill and on the ice (Leger *et al.,* 1980). There are however some specific adaptations that may explain such a lower correlation. Measurement of VO_2max on ice may have been a better choice to validate skating tests at least to know which skating test elicits the highest VO_2max values using portable equipment. Ice skating is much more skill oriented than running and that may also explain lower correlation. To improve accuracy, we plan to investigate some easily measurable biomechanical indices such as the limb frequency at a set speed as was done for swimming (Lavoie *et al.,*1985). On the other hand, although entered in the regression model we used, weight and height of the subjects were not retained as significant predictors. On the other hand, age and gender were not even considered as potential co-predictors because we feel this is inappropriate since, even though general accuracy may increase, it introduces systematic bias. Taking gender and age as co-predictors will just ensure that the average difference in gender or average age effect is automatically applied leading to systematic underestimation of females that really have same VO_2max than males. In a direct test, male and female terminating at the same stage generally have the same VO_2max notwithstanding small differences in mechanical efficiency or measurement errors. With regard to measurement errors, these are more frequent than we think with automated metabolic systems (Babineau *et al.,* 1999) and that is confirmed by the better correlations obtained between maximal treadmill speed (instead of VO_2max) vs. maximal speed achieved in other field tests (Table 3).

Compared to MS20MST, SMAT has similar accuracy (vs. treadmill VO_2max, r=0.73 and SEE=11%) while FAST has much lower one (r=0.41 and SEE=14.7%). This is a bit lower than correlations reported for SMAT in younger 14.7 year old subjects (r= 0.83, SEE=7.0%, Leone *et al.*, 2007) and for FAST in 17-19 juniors players (r=0.67, Faught *et al.*, 2003) and in a large sample (n=532) of mixed age male and female players (9-22 year old, r=0.71 and SEE=12.9%, Petrella *et al.*, 2007). In the latter study however, r is higher because other predictors were included in the regression (weight, height and gender) and because of a wide range of data while SEE, less sensitive to that, is similar to the one found in our study. With the same data, correlations for each age subgroup vary between 0.42 to 0.63; also, for 179 male players aged 19 and above, r was 0.42, very similar to the one obtained in our study. The FAST may thus be less valid because, instructions on how to negotiate the change of direction at each end of the course are not standardized enough and also because, the terminal point is less reliable in a test where the speed increases exponentially with time (as apposed to a linear increase) and a small difference in motivation could make a large difference in the final results of FAST and negatively affects the correlation with treadmill VO_{2max}.

Equivalence between field tests

In our study, FAST was also not well correlated to the other field tests (r<0.67, table 4). Even the gym shuttle run 20MST is better correlated to the two other field tests (r<0.0.83, Table 4) and to treadmill VO_2max (r=0.84, Table 3), confirming its validity. In other words, to be ice skating specific either the MS20MST or SMAT could be used but the 20MST is a good alternative, particularly in developing athletes with whom the ice time is often limited. It is not excluded that another version of the FAST with stage of constant speed increment and constant stage duration would be more accurate.

Systematic differences between tests.

The MS20MST had the lowest maximal skating speed among the skating tests (Figure 3), and even if it correlated well with the treadmill speed, it may be questionable. Although the MS20MST is specific for ice-hockey with its frequent stop and go over a shorter distance than SMAT, it causes rapid muscular fatigue and limits subjects from attaining higher maximal speed. But as long as that speed is well correlated to VO_2max, the final speed is a good indicator of skating aerobic fitness although it does not correspond to speed where VO_2max is attained in steady state condition, the so called Maximal Aerobic Speed (MAS). Thus, with regards to maximal speed, the SMAT allows higher maximal speed, while maintaining a ice-hockey specific nature. When comparing the MS20MST to the SMAT, they have a similar speed increment per min, but the SMAT has a 30 s rest period after each one minute stage, and has a longer course (45 m as apposed to 20 m in the MS20MST), requiring a lower frequency in direction changes and acceleration phases. Thus to reach the same speed in the SMAT is easier and for the same VO_{2max}, subjects reach higher speed in the SMAT. On the other hand, the FAST has no rest between stages, and has not stop-and-go pattern (the FAST is continuous and curvilinear), and the stages of the FAST become shorter and shorter meaning that the speed is increasing faster and faster (after every third length of the ice). In the FAST, subjects obtained much higher final skating speeds, as the course is continuous and curvilinear (without stop-and-go) and allows subjects to build up and maintain high skating speeds. In other words, as the test progresses the subjects have to maintain new speed for less time which enables them to reach higher speeds. So even if that was expected, it needed to be statistically confirmed and quantified which it has been done. This indicates that maximal speeds achieved in each of these three skating tests are different and each test imposes different stimuli and demands different skills from the subjects. Furthermore, since these maximal speeds are linked to the nature of the protocol, they do not reflect the difficulty of the test as they do not vary as lactate or RPE do between tests.

The duration of the treadmill test is the longest, probably because the treadmill protocol has the longest stage duration (2-min).With 2-min stages and 1 km h^{-1} increment per stage, steady state is attained at the end of each stage (Leger *et al.*, 1998), a condition essential to obtain an unbiased measure of VO_2 requirement and the so called MAS. Although total SMAT duration is similar to treadmill one, this is due to introduction of a 30-s rest between stage and with 1-min stage added to a recovery rest, stage are not long enough to reach steady state. Similar problems affect all the field tests of this study but as long as we are solely interested in the prediction of VO2max, the final speeds of these field tests except FAST, appear to be good predictors. Coming back to total test duration, it is clear that MS20MST is the test with the shortest duration, making it the most time efficient. Thus, when ice-time is limited and expensive, it is still possible to administer an on-ice test, if it is time efficient, and for this purpose, the MS20MST would be the best.

In our study, only the FAST maximal heart rate was significantly lower than the treadmill one, while the two other skating tests also show a trend toward that. Others observed larger differences. Hence,Léger, Seliger & Bassard (1979) demonstrated lower maximal heart rates on-ice for both hockey players and runners (10 beats min^{-1}), compared to the treadmill test. Vergès, Flore & Favre-Juvin (2003) also found a significant difference in heart rate during laboratory treadmill running (195.3±6.8 beats min^{-1}) and field roller skiing (190.4±5.6 beats min^{-1}). It is possible that the larger active muscle mass while running versus skating explains these heart rate differences. On the other hand, Petrella (2006) found similar maximum HR during the FAST and treadmill test (190 beats min^{-1} in both tests). We cannot explain these differences.

The MS20MST and the SMAT yielded the highest lactate values and FAST the lowest ones, indicating a higher anaerobic contribution in both the MS20MST and the SMAT, as compared to the FAST and the running tests. This may indicate that the MS20MST and the SMAT are more hockey specific than the other tests.

The perception of less physiological strain in the FAST (Figure 1) may be due to the fact that the FAST is curvilinear in nature (less muscular fatigue as it is continuous with no stop-and-go), and allows subjects to build up speed gradually, and maintain that speed, before the skating speed becomes very fast, and subjects have to stop suddenly without having to sustain fatigue for a long time. It seems that the MS20MST and SMAT have similar perceived intensity despite longer test duration in SMAT. The skating tests are perceived to be easier, but physiologically, they are as taxing as the running tests. This perception may be due to the fact that ice-hockey players are more comfortable in and familiar with their training environment that with running, demonstrating the need for on-ice aerobic tests.

Predicted VO_2max using original equation developed for SMAT and FAST yields similar values to the treadmill VO_2max confirming the external validity of these two skating tests in terms of systematic errors. But as discussed before, FAST has much larger random errors than the two other skating tests.

Specificity of testing and practical aspects.

Testing players in their training environment more accurately reflects the muscular and metabolic demands of the sport, as well as specific adaptations from training (Daub, 1983). Due to the differences in efficiency between running and skating (Léger, Seliger & Brassard, 1979), it is preferable to test ice-hockey players on-ice. In 1976 Simard demonstrated that the best skaters had lower VO_2max in the laboratory, showing that they were much more efficient on the ice and demonstrating that laboratory testing can yield inaccurate results. The availability of the three new skating field tests of aerobic fitness provides the coach and sport scientist with the option of more specific on-ice field tests that are sometimes more time efficient.

Cycle ergometry, treadmill running and treadmill skating offer some variation of metabolically demanding exercise, but do not allow the participant to perform the same mechanics of skating on-ice (Petrella, 2007; Leone *et al.,* 2007 In an attempt to make the measurement of VO_2max more sport specific for ice-hockey, Dreger & Quinney (1999) used a skating treadmill protocol. However, the high cost of such a piece of equipment and it availability may make it unsuitable. The MS20MST and the SMAT are very similar with regard to physiological demand (VO_2, HR, and lactate), RPE, and subjective suitability ratings (Likert scale), in which the skating tests consistently scored higher with regards to similarity to the game of ice-hockey, as well as suitability to assess aerobic and overall fitness in ice-hockey players. This clearly demonstrates the need for on-ice skating tests for the assessment of aerobic fitness in ice-hockey. Furthermore, these new tests allow testing many players simultaneously. In fact Petrella (2006) states that the FAST can comfortably test up to eight ice-hockey players simultaneously, and that a full roster hockey team can be completely evaluated within a typical one hour practice session. When using the SMAT, between 10 and 15 players can be tested on-ice at the same time, depending on their body size (Leone, Léger & Comtios*,* 2006); the same applies for the MS20MST. These tests also require less time than laboratory treadmill testing, less equipment, and are less expensive, as they can be easily administered during a training session, wearing either complete (SMAT and MS20MST) or partial ice-hockey equipment (FAST)

Conclusion

The main purpose of this study was to assess and compare validity and specificity of three aerobic skating tests. For almost all measured variables, FAST has the lowest scores (correlation with treadmill VO_2max, correlations with the two other skating tests (even lower than the 20MST running test), maximal lactate, maximal heart rate, rated perceived exertion and Likert resemblance scores with the hockey game requirements). On the other hand, SMAT and MS20MST revealed similar and much better results as ice hockey specific tests and are to be preferred to the FAST.

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Tables and Figures

Table 1: Subject Characteristics of the Sample Used (n=16)

	Age (yrs)	Years of hockey (yrs)	Height (cm)	Weight in lab (kg)*	Weight with full kit (kg)**	FAST weight (kg)***	Treadmill VO_2max (ml kg-1 min-1)
Mean	32.1	22.0	176.7	78.7	88.6	73.0	51.8
SD	12.7	12.3	7.4	15.0	15.1	7.4	8.6
Minimum	20	3.0	165.0	56.7	67.0	64.0	37.2
Maximum	59	54.0	193.4	117.10	129.0	80.0	64.4

* measured in the laboratory on a calibrated balance scale on the day of treadmill testing
** measured in the ice-arena on a bathroom scale with subjects wearing full kit and holding hockey stick, on the day of MS20MST or SMAT
*** measured in the ice-arena on a bathroom scale with subjects wearing a tracksuit, helmet, gloves and holding hockey stick

Table 2: Characteristics of the maximal multistage running & ice-skating field tests to be used in this study

	20-m shuttle run (20 MST)[1]	**20-m shuttle skate (MS20MST)[2]**	**45-m shuttle skate (SMAT)[3]**	**48.8 m shuttle skate (FAST)[4]**
Source	Léger *et al.* (1988)	Kuisis (2003)	Leone *et al.* (2007)	Petrella *et al.* (2007)
Displacement technique	Shuttle Stop & Go Gym Running	Shuttle Stop & Go Ice Skating 1 hand on stick	Shuttle Stop & Go Ice Skating 1 hand on stick	Shuttle Wide turn Ice Skating 1 hand on stick
Protocol Type	Max Multistage Continuous	Max Multistage Continuous	Max Multistage Intermittent	Max Multistage Continuous
Speed vs. Stage	Linear	Linear	Linear	Curvilinear
Stage duration	1 min	1 min	1 min	45 s → 19.5 s
Rest interval	0 s	0 s	30 s	0 s
Initial speed	8. 5 km h^{-1}	10.0 km h^{-1}	12.6 km h^{-1}	15 s (11.7 km h^{-1})
Speed increase	0. 5 km h^{-1}	~0. 5 km h^{-1}	0.72 km h^{-1}	-5 s (0.4→2.0 km h^{-1})
Equipment	Running shoes	Full hockey kit (+ portable VO_2 system**)	Full hockey kit	Skates, stick, helmet, gloves

** In experimental phase of original study only

[1] VO_2max (ml kg^{-1} min^{-1}) = -27.4 + 6.0 (running speed, km h^{-1}) (Leger *et al.* 1988)

[2] VO_2max (ml kg^{-1} min^{-1})= -33.337 + 6.24*Speed (in km h^{-1}). (This study, n=20)

[3] VO_2max (ml kg^{-1} min^{-1}) = 16.151(maximal skating velocity in skating velocity is in m s^{-1})-29.375 (Leone *et al.* (2007)

[4] VO_2max ={0.428(F-length)} - {0.348(weight in kg)} + {25.434(height in m)} - {11.09(gender, 1=male)} +27.196 (Petrella *et al.*, 2007)

Table 3. Correlations and standard errors of the estimate predicting treadmill VO_2max and maximal speed from field test maximal speed.

Treadmill (Y)	n	Predicted variable	r	SEE ml kg^{-1} min^{-1} or km h^{-1}	SEE %
MS20MST (X)	**21**	**VO_2max**	0.74	5.93	11.2
		Max speed	0.75	1.23	8.07
SMAT (X)	**20**	**VO_2max**	0.73	5.65	11.0
		Max speed	0.79	1.16	7.73
FAST (X)	**20**	**VO_2max**	0.41	7.53	14.7
		Max speed	0.53	1.59	10.6
20MST (X)	**17**	**VO_2max**	0.84	4.69	9.02
		Max speed	0.94	0.70	4.59

Table 4. Equivalence between field tests using regression model without dependant and independent variables.

Independent variable (X)	Dependent variable (Y)	n	r	Y = a + b X* a	b	SEE** km h^{-1}	SEE %
SMAT	**MS20MST**	20	0.84	-1.863	0.866	0.50	3.68
MS20MST	**SMAT**			2.149	1.155	0.58	3.24
20MST	**MS20MST**	16	0.83	3.172	0.837	0.62	4.49
MS20MST	**20MST**			-3.780	1.194	0.73	5.83
20MST	**SMAT**	17	0.87	5.286	1.003	0.62	3.47
SMAT	**20MST**			-5.284	0.998	0.62	4.92
FAST	**20MST**	17	0.67	0.944	0.573	0.99	7.87
20MST	**FAST**			-1.648	1.746	1.73	8.51
FAST	**MS20MST**	19	0.58	4.056	0.472	0.89	6.51
MS20MST	**FAST**			-8.643	2.123	1.89	9.25
FAST	**SMAT**	21	0.61	6.863	0.540	0.95	5.32
SMAT	**FAST**			-12.702	1.852	1.76	8.64

* b of this regression model is obtained dividing b of conventional model by r; then a is obtained substituting average values of Y and X and new value of r in : Y = a + bX

** $SEE = \sqrt{((\sum(Y_{observed}-Y_{predicted})^2)/(n-2))}$ using predicted value with the new model.

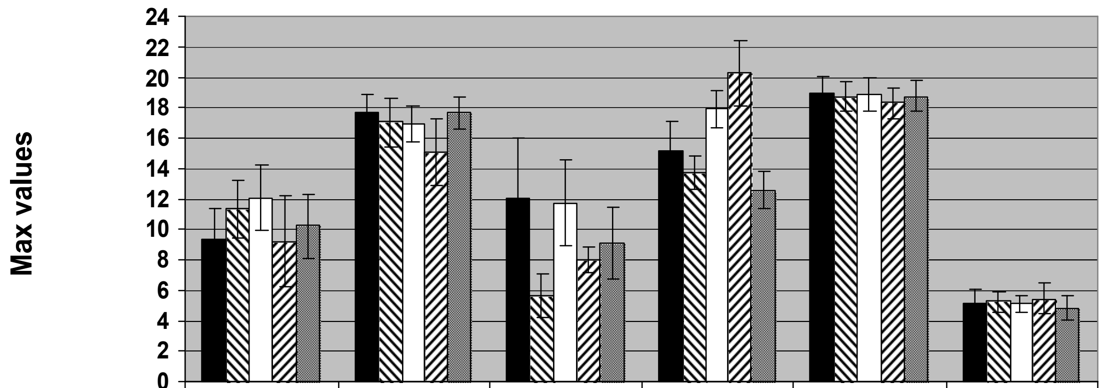
Figure captions

Figure 1: Comparison of maximal values attained in investigated tests (n=16)

Figure 2: Comparison of resemblance scores with ice hockey for investigated tests on the 1 to 7 point Likert scale (1=no, 7= yes)

Figure 3. Scatterplots of maximal treadmill speed as a function of maximal speed of each ice skating test

Figure 1: Comparison of maximal values attained in investigated tests (n=16)



	Lactate	RPE	Duration	Final speed	HR max/10	VO2 max/10
Treadmill	9.36	17.69	12.09	15.13	18.99	5.18
MS20MST	11.33	17.06	5.62	13.72	18.72	5.23
SMAT	12.04	16.93	11.73	17.91	18.91	5.10
FAST	9.19	15.06	8.03	20.28	18.34	5.40
20 MST	10.24	17.69	9.03	12.59	18.76	4.82

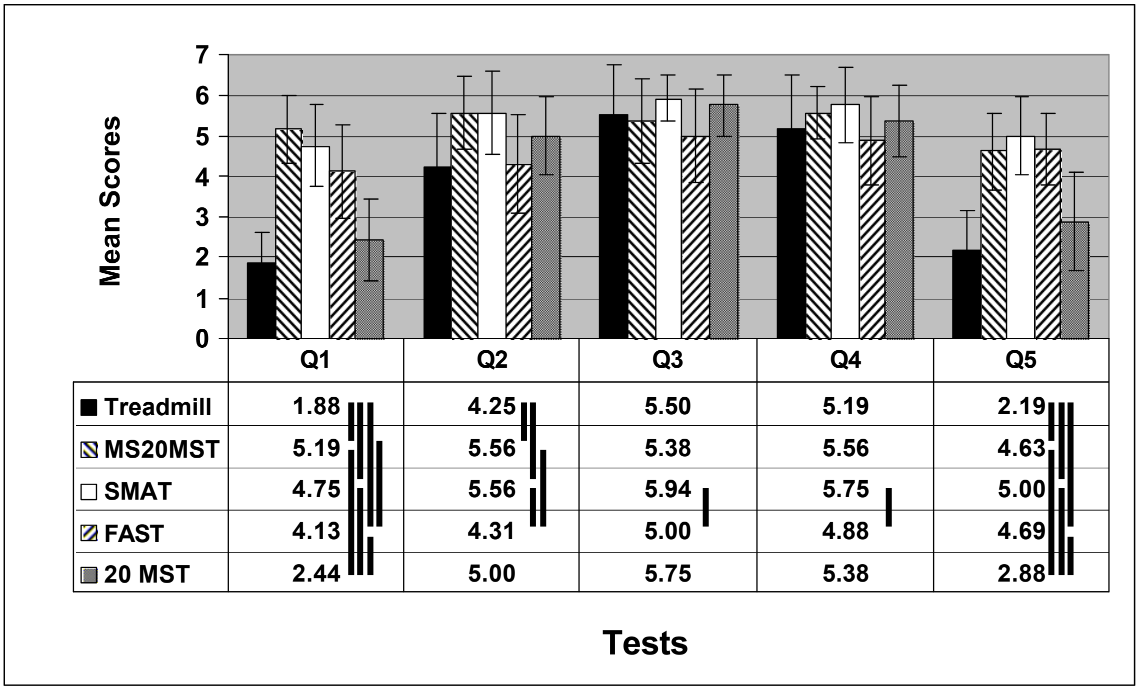
Variables & Tests

Note 1: Lactate is in mmol L^{-1}, RPE is on a scale of 6-20, Duration is in min, Final speed is in km h^{-1}, HR is in beats min^{-1}, VO_2 max is in ml kg^{-1} min^{-1}

Note 2: HR and VO_2 max are divided by 10 so they could be plotted on the same graph.

Note 3: Pairs of values joined by a vertical bar are different ($p<0.05$)

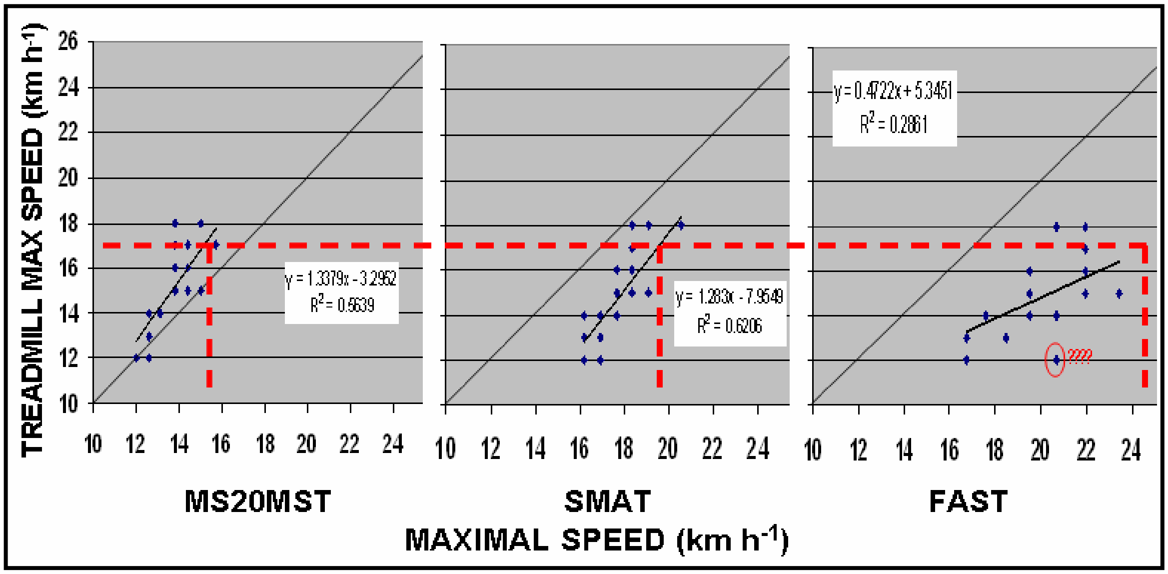
Figure 2: Comparison of resemblance scores with ice hockey for investigated tests on the 1 to 7 point Likert scale (1=no, 7= yes)



Q1 Similarity of basic skating skills (not puck handling) of the test compared to those of a hockey game
Q2 Resemblance between maximal intensity of the test & maximal intensity of a hockey game
Q3 How is the test suited to evaluate aerobic fitness of hockey players?
Q4 How is the test suited to evaluate overall fitness (including muscular & cardiovascular fitness) of hockey players?
Q5 How is the test suited to evaluate overall hockey ability (fitness & skating skills) of hockey players?

Note: Pairs of values joined by a vertical bar are different ($p<0.05$)

Figure 3. Scatterplots of maximal treadmill speed as a function of maximal speed of each ice skating test



Validity of 3 ice skating aerobic field tests for hockey players.

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INTRODUCTION. Three multistage aerobic ice skating field tests have recently been introduced: 1) maximal continuous multistage stop and go 20-m shuttle skating test (Modified Skating 20 MST, MS20MST, Kuisis 2003), 2) maximal intermittent multistage 45-m ice skating shuttle test with stop and go (SMAT, Leone 2006), both using full ice hockey equipment; and 3) maximal continuous multistage 160ft (48.8m) ice skating shuttle test with wide turns wearing only gloves, hockey stick and helmet (FAST, Petrella 2006).

OBJECTIVES and METHODS. The relative validity of these 3 tests was assessed comparing maximal speed of these tests to VO2max (Moxus) and maximal speed of a multistage treadmill test and the gym 20-m shuttle run test (Leger 1988) in 25 adult ice hockey players of various fitness levels but with good skating skills.

RESULTS. Expectedly, maximal speed increased from MS20MST to SMAT and to FAST protocols but the later shows lowest Borg RPE and max lactate and heart rate ($p<0.05$, Repeated ANOVA and Tukey test). Similitude with the intensity of hockey game and suitability as an aerobic test for ice-hockey was also judged lowest by the subjects for the FAST test on a 7 points subjective scale. Compared to treadmill VO2max, correlations were 0.74, 0.73, 0.41 and 0.84 for MS20MST, SMAT, FAST and the 20-m gym test, respectively. Correlations were slightly better with treadmill max speed (0.75, 0.78, 0.53 and 0.94, respectively) due to small but common accuracy problem of VO2measure. Thus using treadmill test as a standard, the FAST is less valid than the 2 others skating protocols admitting that the ice skating protocol that elicits the highest VO2max values would be a better standard. Nevertheless lower HR max and LA max values for the FAST do not support that test. Correlations between the MS20MST, SMAT and 20-m gym tests were around 0.84 but lower between these tests and FAST (around 0.63).

CONCLUSIONS. Based on these results, it is recommended to either use MS20MST or SMAT protocols in elite players if ice time is available or the 20-m gym test otherwise. Future study is needed to identify which test yields highest VO2max values on ice.

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