

The energy cost of dribbling in field hockey

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Abstract

Objective. To evaluate the metabolic and ventilatory responses to normal upright running and dribbling a hockey ball in a semi-crouched position in field hockey players.

Design. Maximal exercise values (heart rate, oxygen consumption, respiratory exchange ratio and minute ventilation) were initially determined in 11 male and 10 female hockey players. Thereafter, the male players completed 4 minutes of treadmill running while running upright and dribbling a ball at the end of a hockey stick at 10, 12 and 14 km.h⁻¹, and the female players at running speeds of 8, 10 and 12 km.h⁻¹. Oxygen consumption, heart rate, respiratory exchange ratio and minute ventilation were measured for each intervention. Lung function was measured at rest in an upright and semi-crouched position.

Results. The resting lung function of both genders was not affected by the simulated dribbling position. Mean oxygen consumption, minute ventilation rate, respiratory exchange ratio and heart rate whilst dribbling a hockey ball were significantly higher ($p < 0.001$) than when running upright for both genders at each running speed. Dribbling a hockey ball for 2 minutes at 14 km.h⁻¹ (males) and 12 km.h⁻¹ (females) resulted in metabolic and respiratory variables reaching near-maximal, maximal and supramaximal levels when expressed as a percentage of those variables attained in the initial treadmill running test.

Conclusions. Dribbling a hockey ball is physiologically more costly than upright running. The postural requirements of dribbling a hockey ball do not limit male or female hockey players' ventilatory performance whilst dribbling.

Introduction

Field hockey is described as a 'field invasive, fast moving territorial game that makes unique physical and physiological demands on the players'.¹³ The advent of the artificial playing surface and the advances in stick construction have changed the skill and physiological requirements of field hockey at all levels, but in particular at the elite level.¹³ In order to cope with the technical evolution within the game, and the increased playing speed, hockey players have had to develop the appropriate physiological and psychomotor skills needed during competition. Unique requirements of field hockey include dribbling the ball and running at speed in a semi-crouched posture. It has been found that between 17% and 30% of the competition time is spent in a semi-crouched position,¹⁰ yet little is known about how these postural changes affect energy expenditure.

In the past the energy cost of playing hockey was inferred from studies assessing the energy cost of running upright on a treadmill.¹⁵ However, the physiological cost of playing hockey is grossly underestimated if the prediction of energy expenditure is based on the speed of locomotion in the upright posture alone.¹⁵ Playing field hockey is classified under the category of 'heavy exercise' and energy expenditure during play has been estimated to be between 30 and 50 kJ.min⁻¹.^{3,12,14} Such an estimate excludes the added strain associated with performing the skill requirements of the game such as playing and dribbling the ball with a hockey stick. The extra energy expended in executing a skill such as dribbling would give an indication of the additional loading over and above the work rate demanded by the game and its pattern of play. Therefore, the aim of this study was to establish the physiological strain in male and female players when dribbling a ball with a hockey stick on a treadmill at various speeds compared with running in an upright position. A secondary aim was to assess whether the semi-crouched posture limits the players' ventilatory capacity.

Methods

Subjects

Eleven male and 10 female South African provincial and international hockey players volunteered to participate in the present study. Before commencement of the study the experimental protocol was explained to all subjects and they gave full-informed written consent. The study was approved by the University of the Witwatersrand's Committee for Research on Human Subjects (M960250).

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Field study

A field study was conducted before commencement of the investigation. Eight male hockey players, who were first-class club players with several years' experience in the game, were asked to dribble a ball in a straight line, as fast as possible, while sprinting over 30 m. Although this test was done on grass rather than on a synthetic pitch, these players reached an average peak running speed of $22.9 \pm 0.3 \text{ km}\cdot\text{h}^{-1}$ (mean \pm standard deviation (SD)), which they would most likely achieve during match play if they were to dribble a ball for 30 m. This result gave an indication that treadmill speeds faster than those used in previous research¹⁵ need to be used in laboratory dribbling tests. However, since running at fast speeds in a crouched position on the treadmill becomes dangerous, we selected maximum test speeds of $14 \text{ km}\cdot\text{h}^{-1}$ for the male hockey players (61% of the average peak running speed) and $12 \text{ km}\cdot\text{h}^{-1}$ for the female players (53% of the average peak running speed for the males). Although these percentages of running speeds may seem low, the players would have to run at these speeds, in a crouched position, for 2 minutes.

Pulmonary function tests

All subjects were asked not to exercise for at least 12 hours before reporting to University of the Witwatersrand Exercise Laboratory for pulmonary function testing, since forced vital capacities (FVCs) have been shown to be reduced temporarily following an acute bout of exercise.⁴ Pulmonary function was assessed at rest, while the subjects were standing in the upright position, and in the semi-crouched position, similar to the position they would adopt in dribbling during match play. Subjects performed 3 FVC manoeuvres into a spirometer (Schiller, SP-200, Baar, UK); the largest value attained was used for data analysis. The lung variables recorded included FVC, forced expiratory volumes at 1.0 second ($\text{FEV}_{1.0}$) and a flow measurement (dV/dt), enabling the measurement of peak expiratory flow rate (PEFR).

Maximal oxygen uptake ($\text{VO}_{2\text{max}}$ test)

Before the maximal oxygen uptake ($\text{VO}_{2\text{max}}$) test, subjects performed a 3-minute familiarisation, adaptation and warm-up period at low speeds (about $8 \text{ km}\cdot\text{h}^{-1}$) on a motorised treadmill (Powerjog M30, Sport Engineering Ltd., Birmingham, England), as recommended by Shephard.¹⁶ After the warm-up, subjects stretched for 5 minutes. Oxygen consumption (VO_2) was then assessed using a continuous incremental exercise protocol. Subjects initially ran for 3 minutes at $12 \text{ km}\cdot\text{h}^{-1}$ (males) and $10 \text{ km}\cdot\text{h}^{-1}$ (females). Thereafter, speed was increased by $1 \text{ km}\cdot\text{h}^{-1}$ per minute until volitional fatigue. Gradient remained constant at 0%. Metabolic and ventilatory measurements were measured continuously using an on-line respiratory gas analysis system (Oxycon-4, Mijnhart, Bunnik, Holland). Heart rate was obtained throughout the test via radiotelemetry (Polar Edge heart rate monitor, Polar Electro, Finland). The test was terminated at volitional exhaustion. During this protocol 16 out of 21 subjects achieved a plateau in VO_2 , i.e. reached their $\text{VO}_{2\text{max}}$.

A plateau was achieved when VO_2 did not increase by more than $2 \text{ ml}\cdot\text{kg}\cdot\text{min}^{-1}$ despite an increase in exercise intensity, in conjunction with the heart rate reaching age-predicted maximum and the respiratory exchange ratio (RER) exceeding 1. Five subjects reached their VO_2 peak since a plateau was not achieved, despite their heart rate reaching age-predicted maximum and their RER exceeding 1. All VO_2 measurements will be referred to as $\text{VO}_{2\text{max}}$ regardless of whether maximum or peak values were attained. The oxygen consumption (VO_2), heart rate (HR), minute ventilation (\dot{V}_E), respiratory exchange ratio (RER), respiratory rate (RR) and tidal volume (V_t) were recorded at the point of $\text{VO}_{2\text{max}}$, and are referred to as the maximal value for each variable.

Experimental protocol - dribbling test

Subjects were asked not to engage in strenuous exercise for at least 24 hours before laboratory testing. Subjects completed 2 experimental trials, upright and crouched running, with each trial consisting of running on a treadmill at 3 different speeds. The 2 experimental trials were normal upright running (carrying a hockey stick, but not dribbling, as in match play when not in control of the ball), and running on the treadmill while controlling a ball at the end of a modified hockey stick. The modified hockey stick had a net, bigger than the ball, at the end of the stick to ensure that the ball remained on the stick, but still allowing the hockey player to manoeuvre the ball. All subjects were asked to dribble the ball, holding the hockey stick in the same way they would hold the stick while dribbling in a hockey match. For the male players, both running and upright trials were carried out at speeds of $10 \text{ km}\cdot\text{h}^{-1}$, $12 \text{ km}\cdot\text{h}^{-1}$ and $14 \text{ km}\cdot\text{h}^{-1}$, each for 4 minutes. The females followed the identical protocol to that of the males, but at speeds of $8 \text{ km}\cdot\text{h}^{-1}$, $10 \text{ km}\cdot\text{h}^{-1}$ and $12 \text{ km}\cdot\text{h}^{-1}$. We had hoped for at least 3 minutes of VO_2 measurements, when running in the crouched posture, to allow for a steady state of oxygen consumption to be achieved, but it was established in a pilot study that 2 minutes of dribbling was about the maximum that could be tolerated by subjects at these speeds. For this reason, the 4-minute dribbling trial started with 2 minutes of upright running, followed by 2 minutes in the dribbling posture. VO_2 , HR, \dot{V}_E , RER, RR and V_t were measured throughout the 4 minutes of exercise with the same system used for the assessment of $\text{VO}_{2\text{max}}$. Physiological values were compared during the final 2 minutes of each test.

The order of the experimental trials and each of the 3 speeds were randomised and subjects were allowed to recover completely between each running trial. All subjects were familiarised with dribbling the hockey ball on the treadmill before experiments began. For the purposes of this study the 3 treadmill speeds used in the dribbling test (viz. 10, 12, and $14 \text{ km}\cdot\text{h}^{-1}$ for males and 8, 10 and $12 \text{ km}\cdot\text{h}^{-1}$ for the females) are referred to as the 'low', 'medium' and 'high' speeds respectively. Three of the 11 male subjects and 1 of the 10 female subjects failed to complete the 2 minutes of dribbling at high speed. These results were omitted from the data analysis for that speed.

Caloric output for each running session

The calorimetric output for each running session was calculated using Lusk's table,¹¹ which is based on the non-protein VO_2 and VCO_2 data of Zunt and Schumburg, and is generally used for indirect calorimetric calculations of metabolic rate, and the percentage of non-protein energy derived from carbohydrate and fat.

Statistical methods

Repeated measures one-way analysis of variance (ANOVA) with Bonferroni post hoc tests were used to analyse HR, VO_2 , RER, V_E , T_v , RR, and energy cost at the different speeds in the upright and dribbling positions, and the VO_{2max} variables, in the female and male groups. Comparison of pulmonary parameters between the 2 different postures were performed using the paired *t*-test. All values are reported as mean \pm SDs.

Results

Subject characteristics

The eleven male subjects had a mean \pm SD age of 19 ± 1 years, height of 1.76 ± 0.06 m and mass of 67 ± 6 kg. The 10 female subjects had a mean \pm SD age of 19 ± 2 years, height of 1.63 ± 0.03 m, and mass of 57 ± 6 kg.

Resting pulmonary function

No significant change in both genders for resting FVC, FEV₁ or PEFR was found between the semi-crouched posture and the upright posture (*t*-test, $p > 0.05$, Table I).

TABLE I. Pulmonary measurements at rest

	Upright position (mean \pm SD)	Semi-crouched position (mean \pm SD)
Males		
FVC (l)	6.3 ± 1.2	6.0 ± 1.2
FEV1 (l)	5.7 ± 1.0	5.7 ± 1.0
PEFR (l.s ⁻¹)	11.8 ± 2.7	11.1 ± 1.2
Females		
FVC (l)	4.2 ± 0.6	4.1 ± 0.6
FEV1 (l)	4.0 ± 0.6	4.0 ± 0.5
PEFR (l.s ⁻¹)	9.1 ± 1.6	8.7 ± 1.7

FVC = forced vital capacity, FEV₁ = forced expiratory volume in 1 second, PEFR = peak expiratory flow rate.
No significant differences were noted between groups ($p > 0.05$).

Maximal oxygen consumption test

The mean maximum oxygen consumption obtained during the initial treadmill running test was 53.6 ± 2.5 ml.kg⁻¹.min⁻¹ in the men and 48.4 ± 2.6 ml.kg⁻¹.min⁻¹ in the women, and the corresponding heart rate was 197 ± 4 beats per minute in the men and 196 ± 7 beats per minute in the women. The highest RER obtained during the initial VO_{2max} test was 1.11 ± 0.04 in the males and 1.13 ± 0.06 in the females. The highest minute ventilation in the males was 143.7 ± 16.8 l.min⁻¹, and in the females 108.5 ± 11.2 l.min⁻¹.

VO_2 , HR and RER responses to dribbling and running upright

Table II shows the metabolic and respiratory variables during upright running and dribbling at the 3 speeds for males and females. The VO_2 , HR, and RER values in both genders, at each of the 3 speeds, were significantly higher when dribbling compared with upright running (ANOVA, $p < 0.001$, Table II). In the case of male subjects dribbling at high speed, there was no significance between VO_2 during dribbling with the ball and VO_{2max} (ANOVA, $p > 0.05$). However, in the female subjects there was a significant difference between the VO_{2max} and the VO_2 dribbling at high speed (ANOVA, $p < 0.05$). For both males and females there were no significant differences between the RER and HR values obtained during the VO_{2max} test and those values achieved dribbling at high speed (ANOVA, $p > 0.05$).

Energy cost of upright running and dribbling a ball

The energy cost (kJ.min⁻¹) of running upright and dribbling a ball at the 3 speeds, in both males and females, is shown in Table II. In the female players, the energy cost of dribbling a ball, compared with upright running at the same speed, was significantly higher at 8 km.h⁻¹ (ANOVA, $p < 0.05$, Table II), but not at the other 2 speeds (ANOVA, $p > 0.05$, Table II). In the male subjects, the energy cost of dribbling a ball compared with upright running at the same speed, was significantly higher at 10 km.h⁻¹ (ANOVA, $p < 0.001$, Table II), and 12 km.h⁻¹ (ANOVA, $p < 0.05$, Table II), but not at 14 km.h⁻¹ (ANOVA, $p > 0.05$, Table II).

Respiratory responses to dribbling and running upright

The respiratory responses to running upright and dribbling at the 3 speeds, in both males and females, is shown in Table II. The minute ventilation and respiratory rate in both genders, at the 3 speeds, were significantly higher when dribbling a ball compared with upright running (ANOVA, $p < 0.001$, Table II). The tidal volume in both genders, at the low and medium running speeds, were significantly higher when dribbling a ball compared with running upright (ANOVA, $p < 0.001$, Table II) but at the high speed there was no statistically significant difference in the T_v when dribbling a ball and running upright for both genders (ANOVA, $p > 0.05$, Table II). No significant difference was found, in both genders, between the respiratory values (V_E , T_v , RR) obtained during the VO_{2max} test and the values obtained when dribbling at the high speed (ANOVA, $p > 0.05$).

Metabolic and respiratory values measured during dribbling at the high speed expressed as a percentage of the values obtained in the VO_{2max} test

Dribbling a hockey ball at the high speeds of 14 km.h⁻¹ in the male players and 12 km.h⁻¹ in the female players resulted in the metabolic and respiratory variables reaching near maximal, maximal and supramaximal levels when expressed as a percentage of those variables obtained during the initial VO_{2max} test (Fig. 1).

TABLE II. Metabolic and respiratory variables during upright running and dribbling at three running speeds (low medium and high) for male and female players

	Low		Medium		High	
	Running	Dribbling	Running	Dribbling	Running	Dribbling
Males						
VO ₂ (ml.kg ⁻¹ .min ⁻¹)	35.1 ± 4.9	45.0 ± 3.6†	42.6 ± 2.6	49.1 ± 2.9†	47.6 ± 2.3	52.2 ± 1.9†
HR (beats.min ⁻¹)	153 ± 12	174 ± 8†	169 ± 10	184 ± 7†	177 ± 7	190 ± 6†
RER	0.84 ± 0.05	1.07 ± 0.07†	0.84 ± 0.03	1.14 ± 0.08†	0.86 ± 0.08	1.16 ± 0.09†
VE (l.min ⁻¹)	66.4 ± 11.7	102.5 ± 17.7†	87.1 ± 12.8	129.2 ± 19.9†	106.5 ± 14.6	149 ± 25.4†
Tv (l)	2.10 ± 0.84	2.44 ± 0.50*	2.22 ± 0.71	2.51 ± 0.54*	2.40 ± 0.64	2.53 ± 0.48
RR (breaths.min ⁻¹)	35.0 ± 10.9	43.2 ± 10.2*	41.9 ± 11.3	53.1 ± 11.3*	46.7 ± 10.9	59.8 ± 9.6*
Energy cost (kJ.min ⁻¹)	47.8 ± 7.4	61.8 ± 5.4*	58.1 ± 4.3	67.3 ± 6.1*	65.4 ± 3.9	71.2 ± 6.6
Females						
VO ₂ (ml.kg ⁻¹ .min ⁻¹)	29.4 ± 2.8	36.8 ± 3.1†	35.4 ± 2.6	41.0 ± 2.9†	39.8 ± 2.3	43.9 ± 2.0†
HR (beats.min ⁻¹)	145 ± 19	166 ± 15†	164 ± 17	180 ± 13†	178 ± 12	189 ± 11†
RER	0.84 ± 0.04	1.00 ± 0.06†	0.87 ± 0.05	1.08 ± 0.08†	0.91 ± 0.06	1.17 ± 0.07†
VE (l.min ⁻¹)	51.0 ± 10.2	71.9 ± 12.5†	64.8 ± 12.3	88.4 ± 14.7†	82.1 ± 13.1	108.6 ± 14.1†
Tv (l)	1.50 ± 0.22	1.86 ± 0.24*	1.78 ± 0.22	2.04 ± 0.22*	1.89 ± 0.22	2.01 ± 0.26
RR (breaths.min ⁻¹)	34.5 ± 7.0	39.0 ± 6.4*	37.0 ± 8.2	43.7 ± 8.2*	3.8 ± 7.2	55.0 ± 11.3*
Energy cost (kJ.min ⁻¹)	34.0 ± 5.0	42.1 ± 5.8*	41.0 ± 5.1	47.5 ± 6.2	46.4 ± 5.5	51.2 ± 5.4

VO₂ = oxygen consumption; HR = heart rate, RER = respiratory exchange ratio; VE = minute ventilation; Tv = tidal volume; RR = respiratory rate.

Statistical comparisons were made between running upright and dribbling at each speed. The symbols refer to the p-values obtained when running upright was compared with dribbling at the same speed. * p < 0.05 † p < 0.001

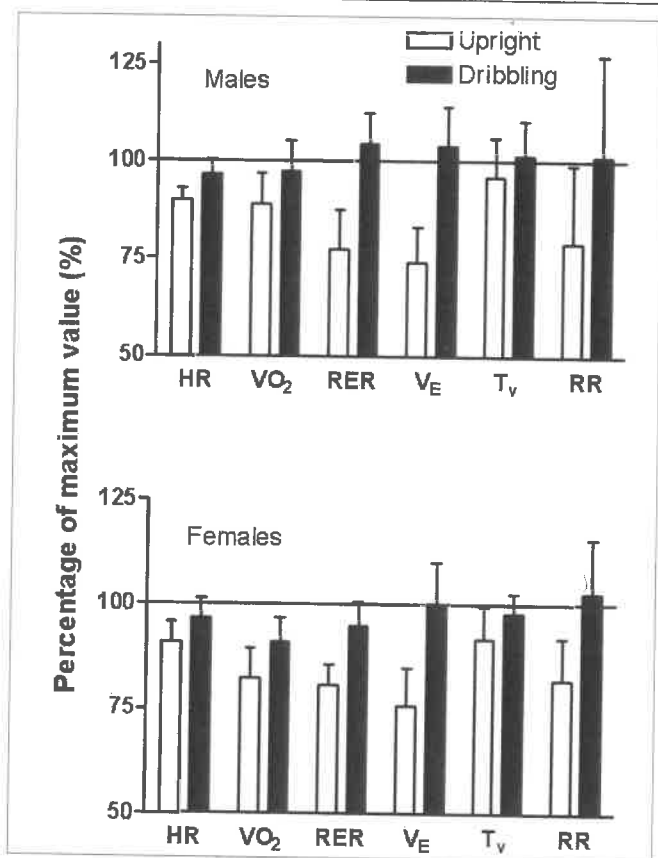


Fig. 1. Percentage of peak values for heart rate (HR), oxygen consumption (VO₂), respiratory exchange ratio (RER), minute ventilation (V_E), tidal volume (T_v) and respiratory rate (RR) (mean ± SD) for both normal upright running and dribbling a ball at the end of a hockey stick in male hockey players (N = 8) at 14 km.h⁻¹ and female hockey players (N = 9) at 12 km.h⁻¹. Each variable was calculated as a percentage of that variable obtained in the VO_{2max} test. The solid line indicates 100% of each variable.

Discussion

Our study aimed to establish the physiological strain in male and female hockey players when dribbling a ball at the end of a hockey stick compared with running in an upright position, and whether the dribbling posture is limiting to a player's ventilatory capacity. Our results show that for both males and females, and at each of the running speeds, the dribbling posture resulted in significant increases in the VO₂, HR, RER, V_E, and RR when compared with upright running at the same speed (Table II). In addition, in both genders, HR, RER, V_E, RR and T_v, at volitional exhaustion in the VO_{2max} test, were not statistically different from those values measured when dribbling at the high running speed. Dribbling a hockey ball at the high speeds of 14 km.h⁻¹ in the male players and 12 km.h⁻¹ in the female players resulted in the metabolic and respiratory variables reaching near-maximal, maximal and supramaximal levels when expressed as a percentage of those variables obtained during the initial VO_{2max} test (Fig. 1). The above results clearly illustrate that the dribbling posture, when compared with upright running, does indeed increase the physiological strain experienced by the hockey players. However, since there was no statistical difference between the lung function measurements (FVC, PEFR, FEV₁) at rest (Table I), in an upright and simulated dribbling posture, the crouched posture of dribbling does not negatively impact on the pulmonary functional capacity of a hockey player.

Our study used treadmill testing to indirectly evaluate the energy cost of running upright and dribbling a ball in field hockey. Our treadmill measurements did not take into account the directional changes that are made in both the upright and semi-

crouched positions, which could increase the energy cost of the activity. In addition, the friction of a ball rolling on a treadmill and astroturf surface may differ and this may influence the energy cost when dribbling a ball on either surface. In addition, a player will never run continuously in a crouched position. An advantage of our protocol is that treadmill testing does give an indication of how a semi-crouched dribbling posture increases the energy cost of running, without confounding variables. In order to safely measure VO_2 for at least 2 minutes of semi-crouched running, we chose treadmill running speeds which were notably slower than the running speeds achieved in a game of hockey. Therefore, at faster more realistic dribbling speeds, the energy cost would certainly be greater. In addition, 2 minutes might be insufficient time for VO_2 to reach a steady state, and as a result the energy cost may have been underestimated.

Examination of the physiological responses to running in the semi-crouched position at speed has revealed significant increases in both metabolic and ventilatory demands, over and above those of normal running in both male and female players. Dribbling a hockey ball increased the VO_2 , compared with upright running, by 29%, 14% and 9% for the male players at the 3 respective speeds, and by 24%, 15% and 9% for the female players, at each of the 3 respective speeds investigated. After each of the 3 running speeds, the RERs, in both genders, were 1.00 or higher as a result of the dribbling posture (Table II). The substantial increase in the RER in the dribbling trials highlights the increased need for anaerobic energy generation in this strenuous posture,⁶ but not in the upright position.

Despite our treadmill running speeds being slower than realistic match play speeds, the high speed (12 km.h⁻¹ in females and 14 km.h⁻¹ in males) used during the study produced near-maximal, maximal, and in some cases supramaximal VO_2 , HR, V_E and RER values compared with the values obtained in the initial $\text{VO}_{2\text{max}}$ test (Fig. 1). Therefore, dribbling a ball requires an extremely high metabolic cost. Three of the male players and 1 female player exceeded their measured $\text{VO}_{2\text{max}}$ during their high-speed dribbling trial. Using Lusk's table,¹¹ we estimated that the dribbling posture increased the energy output in the male subjects by 14 + 9 kJ.min⁻¹ at the low speed (10 km.h⁻¹), by 9 + 3 kJ.min⁻¹ at the medium speed (12 km.h⁻¹), and by 6 + 4 kJ.min⁻¹ at the high speed (14 km.h⁻¹). In the female players, the energy output, as a result of the dribbling posture, increased by 9 + 3 kJ.min⁻¹, 7 + 3 kJ.min⁻¹, and 4 + 3 kJ.min⁻¹ at the low, medium and high speeds respectively. The increased energy cost incurred by our players is less than that shown by Reilly and Seaton,¹⁵ who found that dribbling a ball at 8 and 10 km.h⁻¹ in male players increased the energy cost by 16 kJ.min⁻¹ and 21 kJ.min⁻¹ at each running speed respectively. The differences in energy cost could result from Reilly and Seaton measuring VO_2 for 4 minutes, whereas we measured VO_2 for 2 minutes only, and a steady state may not have been achieved. Despite our smaller increases in energy cost, compared with Reilly and Seaton, we have shown that dribbling entails increased energy expenditure when moving at a given speed compared with normal running. The biome-

chanical and energy demands of running in the semi-crouched position, which is crouched over a stick, exceed those of normal running, and may be accounted for by additional postural work together with the arm and shoulder muscle activity when using the hockey stick.

The increased oxygen cost incurred in the semi-crouched dribbling position has also been shown to be increased in cyclists who cycle in a crouched position, compared with an upright position. Gnehm *et al.*⁵ reported that VO_2 and HR in a crouched position were significantly higher compared with upright cycling. Grappe *et al.*⁷ confirmed that the ventilation, RER, blood lactate, and perceived exertion were all significantly higher in the dropped posture of cycling (semi-crouched) compared with upright cycling. Gnehm *et al.*⁵ hypothesised that the increase in metabolic cost for crouched cycling compared with upright cycling might result from the muscle mass in the shoulder girdle, neck, and arms which are recruited to support an extreme forward position on the bicycle. In our study the increased metabolic cost of dribbling a ball compared with upright running could therefore result from the added postural muscle activity associated with the unilateral position, as well as the added upper-limb activity associated with controlling a ball at the end of a hockey stick. The increase in hip flexion may also alter flow resistance in the iliac and femoral vessels, thus accounting for the higher cardiac energy expenditure.⁵

From a subjective standpoint it appears that restrictions in pulmonary function may be another factor responsible for higher metabolic cost in the dribbling position. However, we found no significant decreases in FVC or PEFRs as a result of the semi-crouched posture. It has been shown that PEFR is reduced in the sitting subject,^{1,8} and that a balance of opposing forces on the thoracic cavity influences flow of air;⁹ however, no significant differences were found in the semi-crouched position. In addition, compared with upright sitting, the PEFR has been shown to be reduced when the head is tilted downwards,² as would occur in the dribbling position. However, in our study, the dribbling posture did not impact negatively on the PEFR.

The intermittent nature of the activity during match play and the physiological cost of accelerating, decelerating and changing the direction of motion adds to the energetic requirements of the game.³ Furthermore, our results have shown that the dribbling posture does indeed increase the energy cost of the game. As a result, it is reasonable to suggest that specific training of maximal aerobic and anaerobic power must be some of the fundamental components in a physical training programme for hockey players. Thus, players should devote considerable time in their training particularly to the arduous task of running, performing sprints, and practising their dribbling skills while controlling the ball at speed.¹⁴

In summary, our study has established that dribbling a hockey ball at the speeds slower than the contemporary game imposes extreme metabolic and ventilatory cost. Our study confirms that the physiological cost of hockey play will be underestimated if the prediction of energy expenditure is based on the speed of locomotion in the upright posture alone. Also,

our study indicated that this peculiar postural requirement of field hockey does not limit the players' ventilatory performance during semi-crouched running. Further research is needed to examine the biomechanical factors associated with the dribbling posture, and attempts made to directly measure the physiological demands of match play in field hockey. Until then, a more game-specific treadmill protocol, incorporating an intermittent crouched and upright running position, is needed to indirectly measure the added physiological strain of dribbling a hockey ball compared with upright running.

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Atlas of Amputations and Limb Deficiencies: Surgical, Prosthetic, and Rehabilitation Principles, Third Edition

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