PROGNOSIS AFTER POPLITEAL ARTERY ENTRAPMENT SYNDROME SURGERY

by

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ABSTRACT

The main purpose of this study was to determine the prognosis after Popliteal Artery Entrapment Syndrome (PAES) surgery for young, active individuals. The hypothesis was that after PAES surgery, full restoration of activity level and sport performance with improvements in exercise-induced leg pain (EILP) and activity tolerance occurs when the surgery is carried out at an early stage of the condition.

Twenty-three subjects all having had PAES surgery were interviewed and visual analogue scales were used to record data on: 1) activity levels, 2) performance levels, 3) intensity of leg symptoms and 4) intensity of activity tolerated. The above information was evaluated at three different times: 1) prior to the development of symptoms, 2) at the peak of symptoms (preop), and 3) at the present time (follow-up). Each individual underwent a medical evaluation as well as Duplex Ultrasonography of the affected popliteal artery (ies). Lastly, the subjects performed a progressive treadmill test. Control subjects that were matched for age, sex and education level were recruited for comparison.

Results showed that the treatment group's activity level did not change significantly over the time periods. However, the treatment group experienced a significant decrease in its activity from its premorbid level to its current level when compared with the control group ($p < .001$). Reviewing the performance data, it was evident that the development of PAES caused a significant drop in activity performance for affected individuals ($p < .001$). Furthermore, the performance did not return to presymptomatic levels after surgery. This result was observed when the treatment group was evaluated on its own ($.02 > p > .05$) and also when compared with the control group ($.01 > p > .001$).

The combination of PAES surgery and time did bring about a significant decrease in leg symptoms while exercising when compared with the control group ($p < .001$). Similarly, an increase in the intensity of activity possible before symptom onset was noted after surgery when compared with the control group ($p < .001$).

A prospective study of PAES patients would be valuable to further define the prognosis for individuals undergoing PAES surgery.

TABLE OF CONTENTS

ABSTRACT	ii
LIST OF TABLES	v
LIST OF FIGURES	vi
LIST OF ABBREVIATIONS	vii
ACKNOWLEDGEMENT	viii
<u>CHAPTER</u>	
1. INTRODUCTION	1
2. METHODS	
Patient Selection	2
Exclusion Criteria	3
Assessment	3
Control Subjects	5
Statistical Treatment of Data	5
3. RESULTS	
General Results	6
Main Results	11
Activity Level Data	11
Performance Data	14
Intensity of Symptoms Data	17
Intensity of Activity Required for Symptoms Data	19
Treadmill Results	21
Duplex Ultrasonography Results	23
Duplex / Clinical Correlation Data	24
Patient Satisfaction Results	28
4. DISCUSSION	
Discussion of General Results	30
Discussion of Main Results	35

Discussion of Activity Level Data	35
Discussion of Performance Data	37
Discussion of Symptoms Data	38
Discussion of Duplex Ultrasonography Results	40
Discussion of Patient Satisfaction Results	42
 6. LIMITATIONS OF THE STUDY	 44
 7. SUMMARY	 46
 8. CONCLUSIONS	 47
 9. RECOMMENDATIONS	 48
 REFERENCES	 49
 APPENDIX I	
Review of the Literature	
History	52
Etiology and Epidemiology	52
Classification	54
Pathology	57
Clinical Features	57
Investigation	59
Differential Diagnosis	61
Treatment	62
Prognosis	62
 APPENDIX II	
Questionnaire for PAES Surgery	66

LIST OF TABLES

TABLE	PAGE
3.1 Reconstructive Procedures	8
3.2 Postoperative Complications	9
3.3 Compartment Syndromes and PAES	10
3.4 Duplex/Clinical Correlation Data	24
3.5 Duplex/Clinical Correlation Data	25
3.6 Duplex/Clinical Correlation Data	26
3.7 Duplex/Clinical Correlation Data	27

LIST OF FIGURES

FIGURE	PAGE
3.1 Anatomic Findings at Surgery	7
3.2 Activity Levels of Treatment and Controls	11
3.3 The Contribution of EILP to Changes in Activity	13
3.4 Performance Levels of Treatment and Controls	14
3.5 The Contribution of EILP to Changes in Performance	16
3.6 Intensity Levels of EILP in Treatment and Controls	17
3.7 Intensity of Activity Required to Develop EILP in Treatment and Controls	19
3.8 Number of Individuals who Developed Leg Symptoms on the Treadmill	21
3.9 Time To Develop Symptoms on the Treadmill	21
3.10 Reasons for Stopping the Treadmill Test	22
3.11 Length of Time on the Treadmill	22
3.12 Preop and Follow-Up Duplex Results for All Limbs with PAES	23
3.13 Patient Evaluation of PAES Surgery	28
3.14 Evaluation of Overall Satisfaction With PAES Surgery	29
II.1 Classification of Popliteal Artery Entrapment Syndrome	56

LIST OF ABBREVIATIONS

Exercise-induced leg pain = EILP

Popliteal Artery Entrapment Syndrome =PAES

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INTRODUCTION

Popliteal Artery Entrapment Syndrome (PAES) is a rare cause of exercise-induced leg pain (EILP). Entrapment occurs because of an abnormal relationship between the popliteal artery and the surrounding myofascial structures in the popliteal fossa. Arterial insufficiency in the affected limb arises with entrapment of the artery, commonly giving leg symptoms with exertion.

The true incidence of PAES in the general population is not known (6). The etiology of PAES has an embryological basis related to the development of the popliteal artery and the surrounding musculature (41). Many different classification schemes have been developed to differentiate the various types of abnormal anatomy that are associated with the syndrome (20,21,23). Repeated popliteal artery compression causes trauma to the arterial wall, leading to premature localized atherosclerosis. The pathology of PAES is believed to be progressive, with arterial thrombosis occurring in some individuals as a natural progression of the disease process (16). Acute ischemia can occur if there is an occlusion of the artery or thrombosis within an aneurysm.

Clinically, up to 85% of the individuals diagnosed with the syndrome are males (13). The mean age of individuals in a large series was 28 years (6). The condition can be found bilaterally in up to 67% of cases (16). Most individuals present with exercise-induced leg pain; with the remainder presenting with acute or chronic ischemia (6).

The condition can result in significant functional loss for active individuals. Surgery has been advocated to prevent the progression of the disease that is believed to be the natural history of untreated PAES. However, the scant research that has been done to determine the prognosis for individuals who have undergone surgery has focused on the patency rate of the arteries after surgery and the presence or absence of complications. This study looks at the prognosis for individuals after surgery in terms of their functional status. The hypothesis of the study was that after surgery, full restoration of activity level and performance with improvements in exercise-induced leg symptoms and activity tolerance occurs when the surgery is carried out at an early stage of the condition in young individuals.

METHODS

Patient Selection

Subjects for the study all had surgery for PAES prior to December 31st, 1995. Additionally, all subjects were under 40 years of age at the time of surgery. The majority of subjects were seen in consultation at the Allan McGavin Sports Medicine Centre, which is an academic referral-based sports medicine clinic affiliated with the University of British Columbia. A mainframe computer registry utilizing a diagnosis of Popliteal Artery Entrapment Syndrome from January 1990 to December 1995 generated the subject names. Furthermore, subjects referred by other physicians in British Columbia to the participating vascular surgeons at The University of British Columbia within the past 6 years were included. These additional subjects were obtained through a review of the surgeon's medical records.

The study was limited to individuals who underwent surgical management for angiographically-confirmed PAES. All individuals had surgery performed by one of three participating vascular surgeons with appointments at the University of British Columbia. The preoperative criteria used to diagnose PAES were: 1) history and physical examination consistent with PAES, 2) non invasive vascular testing results suggestive of vascular obstruction at rest, post-exercise or in positions of provocation and 3) an angiogram with a high grade stenosis or occlusion of the popliteal artery (arteries) at rest or in positions of provocation or 4) Magnetic Resonance Imaging (MRI) suggestive of entrapment of the popliteal artery (arteries).

The study was approved by the Clinical Screening Committee For Research And Other Studies Involving In Human Subjects at The University of British Columbia.

Exclusion Criteria

There was no formal exclusion criteria in the study as this was primarily a descriptive exercise. However, patients who refused to participate in the study were excluded. Patients with significant comorbid conditions that developed prior to the onset of PAES and in the postoperative period were analyzed on an individual basis.

Assessment

All individuals were contacted by mail and invited to participate in the study. The interview process was standardized. Subjects were not informed of any hypothesis regarding the outcome of the study.

The study had 4 parts:

- 1) Questionnaire
- 2) History and Physical Examination
- 3) Vascular Testing
- 4) Treadmill Testing

All testing was completed in one visit to the Allan McGavin Sports Medicine Centre and one visit to the vascular laboratory at The Vancouver Hospital and Health Science Centre-UBC Site.

1) Questionnaire

All subjects initially completed a standardized questionnaire (Appendix 1) including visual analogue scales with the aid of an unblinded interviewer .

2) History and Physical Examination

Subjects then underwent a history and physical examination by a physician, focusing on other medical problems that may have been sources of comorbidity. These might include stress fractures, periostitis, compartment syndromes or other causes of exercise-induced leg pain. Additionally, the cardiorespiratory risk involved in treadmill testing was assessed.

3) Vascular Testing

An examination was undertaken of the patency of the popliteal artery (arteries) via Duplex Ultrasonography with the ankle in: 1) a-neutral position and 2) a position of plantarflexion. The Duplex examination was evaluated in a blinded fashion according to the following chart modified from that originally proposed by Akkersdijk *et al.* (43):

**PEAK SYSTOLIC VELOCITY (PSV) IN
THE DISTAL POPLITEAL ARTERY
DURING PLANTARFLEXION OF THE FOOT DEGREE OF ENTRAPMENT**

1)	PSV=0	OCCLUSION
2)	PSV $\geq$ 2.5X NEUTRAL*	SIGNIFICANT FLOW REDUCTION
3)	PSV $\leq$ 40cm/s	LOW FLOW STATE
4)	PSV>40cm/s but <2.5X NEUTRAL	NORMAL

*PSV $\geq$ 2X neutral originally used by Akkersdijk *et al.* (43)

Preoperative Duplex examinations were obtained from the medical chart.

4) Treadmill Testing

Subjects finally participated in a graded treadmill test supervised by a physician. The test started at a treadmill speed of 3 km/h, with an increase in speed of 1 km/h every minute until a speed of 10km/h was reached. At this speed a grade of 10 degrees was introduced. The treadmill speed was kept at 10km/h for a period of 5 minutes. After which the speed was again increased by 1 km/h per minute. The subject was encouraged to continue with the test as long as possible. During the test symptoms volunteered by the patient and the reason for stopping the treadmill test were recorded.

Control Subjects

Control subjects underwent the same testing protocol except that they did not have a Duplex Ultrasonography examination. They were matched to the treatment subjects with respect to age, sex and educational level.

Statistical Treatment of Data

Student's t tests were performed when comparing different groups of data. The only exception to this was the Chi-Square Analyses done on the Duplex/Clinical Correlation Data in Tables 4.4-4.7. Data was considered to be significant if $p < .05$ with a 2 tailed analysis.

RESULTS

GENERAL RESULTS

Twenty-nine individuals were eligible for the study. Twenty-three individuals (18 females (78%), 5 males (22%)) were studied. The six individuals (3 males, 3 females) who were not involved in the study had a mean age of 26.7 years (Range 20-35, S.D. 6.44). Three individuals did not participate in the study because they lived outside of the province. Two individuals did not participate because they were not interested in the research. Tragically, one individual (22 year old male) died 11 days postoperative as the result of bilateral pulmonary emboli.

The mean age for all research subjects at the time of the study was 24.9 years (Range 14-41, S.D. 7.97). Looking at the males, the mean age was 34.2 years (Range 30-41, S.D. 4.32); the females were significantly younger ($0.025 < p < 0.05$, 2 tail) at 22.3 years (Range 14-38, S.D. 6.72). Twenty individuals had bilateral surgery (87%) and 3 individuals had unilateral surgery (13%). This gave a total of 43 limbs operated on for PAES.

Of the 20 individuals who had bilateral surgery, 17 (85%) had bilateral symptoms and 3 (15%) had unilateral symptoms. Thus, 3 asymptomatic limbs were operated on. Of the 3 individuals who had unilateral surgery, 2 had unilateral symptoms. The other individual had bilateral symptoms of unequal intensity. At the time of the study, he was contemplating having the less symptomatic limb operated on. Considering all individuals operated on for PAES ($n=23$), 18 (78%) individuals had bilateral symptoms and 5 (22%) had unilateral symptoms.

The mean overall age at diagnosis was 22.2 years of age (Range 13-39, S.D. 8.12). Looking at sex differences, the mean age for males was 31.4 (Range 27-39, S.D. 4.82) and the mean age for females was 19.6 years of age (Range 13-37, S.D. 6.92). Comparing the two sexes with respect to age, there was not a significant difference ($0.05 < p < 0.10$, 2 tail) between the groups.

The length of time from the onset of symptoms to the correct diagnosis (defined as the date of the angiogram confirming PAES) was 25 months (Range 3-60, S.D. 18.98). The mean length of time for follow-up after surgery was determined to be 29.5 months or 2.5 years (Range 3-124, S.D. 27.70).

The mean time from surgery to return to work/school was found to be 2.8 weeks (Range 1 day-10 weeks, S.D. 2.51 weeks). The time from surgery to return to provocative activity was 8.8 weeks (Range 2-16, S.D. 3.54). One individual was unable to return to the activity that brought out symptoms because of persistent pain with that activity.

In FIGURE 3.1, the anatomic findings at surgery of the subjects are recorded. Of note, in 2 individuals, 2 different anatomic lesions were found (accessory slip of medial gastrocnemius and fascial bands, scarring of the popliteal artery to the tibia and fascial bands). All individuals with bilateral surgery had similar findings in both limbs.

Of the 23 individuals in the study, 21 underwent simple myofascial release of the involved arteries. The other 2 individuals eventually underwent reconstructive procedures (TABLE 3.1).

TABLE 3.1. RECONSTRUCTIVE PROCEDURES

1. 17 year old female

Right PAE Release---->Vein Patch Angioplasty---->Popliteal Bypass
Graft

Left PAE Release---->Vein Patch Angioplasty---->Release of
Adhesions Compressing Popliteal Artery

2. 27 year old male

Right Narrowing of Popliteal Artery in Neutral Position on Angiogram
Release of PAE With Vein Patch Angioplasty---4 Years--->
Femoral/Tibial Bypass After Acute Thrombosis

Left Narrowing of Popliteal Artery in Neutral Position on Angiogram
Release of PAE----6 Years--->Popliteal Artery Bypass after Acute
Thrombosis

Postoperative complications including the age and the outcome are recorded in TABLE 3.2.

TABLE 3.2. POSTOPERATIVE COMPLICATIONS

- 1. Sural Neuropathy** **41 year old male**
--> Numbness in foot still present 15 months after surgery
- 2. Hypertrophic Scarring** **32 year old female**
--> Required cortisone injections
--> Patient remains unhappy with cosmetic result
- 3. Popliteal Fossa Hematoma** **34 year old male**
--> Required drainage under local anesthesia 1 week post-operative
--> Resolved without further sequelae

Four individuals in the study had undergone fasciotomies for confirmed chronic compartment syndrome in addition to their PAES surgery. The location of the fasciotomies and the time of the surgery in relation to the PAES surgery is detailed in TABLE 3.3.

TABLE 3.3. COMPARTMENT SYNDROMES AND PAES

<u>Compartment Surgery Pre-PAES</u>	
	<u>Number of individuals</u>
Anterior	2
4 Compartment	1
 <u>Compartment Surgery Post-PAES</u>	
	<u>Number of individuals</u>
Lateral	1
	—
Total	4

Control Subjects

Twenty-three (18 females and 5 males) were recruited for the study. The average age of the control subjects was 26.6 years of age (Range 20-37, S.D. 3.10). This was not significantly different ($0.3 < p < 0.4$, 2 Tail) than the 24.9 years of age calculated for the treatment group.

MAIN RESULTS

ACTIVITY LEVEL DATA

Treatment Group

It was determined from the activity data (FIGURE 3.2) that there was no significant change in any activity patterns for the treatment group over the time periods ((1) **Prior-Peak Mean=1.77, S.D.=4.35, .1>p>.05, 2 Tail** (2) **Peak-Present Mean=-1.28, S.D.=4.89, .3>p>.2, 2 Tail** (3) **Prior-Present Mean=0.49, S.D.=3.76, p>0.5, 2 Tail**). However, there was a decrease in activity from the onset of symptoms to the time they reached their peak intensity. Additionally, there was an increase in activity after surgery at follow-up time from the level at peak pain, but these were not significant.

Control Group

The control group increased its activity level over the three time periods, although not significantly ((1) **Prior-Peak Mean=-0.72, S.D.=2.30, .2>p>.1, 2 Tail** (2) **Peak-Present Mean=-0.64, S.D.=2.93, .4>p>.3** (3) **Prior-Present Mean=-1.37, S.D.=3.72, .1>p>.05, 2 Tail**).

Treatment vs. Control Group

When comparing the treatment and control groups (**TREATMENT-CONTROL**), the difference from the time period Prior to the time period Peak was significant (**Prior-Peak Mean=2.50, S.D.=1.02, .05>p>.02, 2 Tail**). During this time period the treatment group decreased its activity whereas the control group increased its activity. Both the treatment and control groups increased their activity from Peak to Present and the difference between these groups was not significant (**Peak-Present Mean=-0.64, S.D.=1.19, p>.5, 2 Tail**). Furthermore, the change from Prior to Present for the treatment group was an overall decrease in activity, but for the control group it was an overall increase (**Prior-Present Mean=1.86, S.D.=1.10, p<.001, 2 Tail**). Comparing these two groups the difference was significant.

FIGURE 3.3, THE CONTRIBUTION OF EILP TO CHANGES IN ACTIVITY LEVELS

In FIGURE 3.3 the contribution of EILP to explain the observed changes in activity levels was recorded. EILP was cited as a cause for changes in activity much more frequently in the treatment group, than in the control group. Although 14 of 22 individuals stated that EILP was very important to their change in activity from Prior to Peak, only 7 of 22 thought it was very important to explaining their change from Prior to the Present time.

PERFORMANCE DATA

Treatment Group

Looking at the results for performance (FIGURE 3.4), the treatment group follows the same pattern as with activity level data (FIGURE 3.2). That is, there is a decrease in performance from the Prior to the Peak time period (**Prior-Peak Mean=3.40, S.D.=3.96, $p<.001$, 2 Tail**). However, unlike the activity data, it is a significant decrease. There was a non significant increase in performance from Peak to the Present time (**Peak-Present Mean=-1.46, S.D.=5.55, $.3>p>.2$, 2 Tail**). Furthermore, there was a significant decrease in performance from Prior to the Present time (**Prior-Present Mean=1.94, S.D.=3.98, $.05>p>.02$, 2 Tail**).

Control Group

Looking at the controls, they increased their performance over the three time periods. However, only the changes from Peak to Present and Prior to Present were significant (**(1) Prior-Peak Mean=-0.58, S.D.=3.56, .5>p>.2, 2 Tail (2) Peak-Present Mean=-1.24, S.D.=2.75, .05>p>.02, 2 Tail (3) Prior-Present Mean=-1.82, S.D.=3.29, .02>p>.01, 2 Tail**).

Treatment vs. Control Group

Comparing the treatment and control groups (**TREATMENT-CONTROL**) during the time period Prior to Peak, the difference was significant (**Prior-Peak Mean=3.97, S.D.=1.11, .01>p>.001, 2 Tail**). In this time period the treatment group decreased its performance whereas the control group increased its performance. However, both groups increased their performance from Peak to Present and the difference was not significant (**Peak-Present Mean=-2.13, S.D.=1.29, p>.5, 2 Tail**). The change from Prior to Present for the treatment group was an overall decrease in performance, but for the control group it was an overall increase. Comparing these two groups the difference was significant (**Prior-Present Mean=3.76, S.D.=1.08, .01>p>.001, 2 Tail**).

In FIGURE 3.5 the contribution of EILP to explain the observed changes in performance levels was recorded. As with the activity data, EILP was cited as a cause for changes in activity much more frequently in the treatment group than in the control group. Moreover, the pattern of decreased importance of EILP to explain changes in performance in the treatment group for the time period Prior to Present (7 individuals) compared with Prior to Peak (16 individuals) was also similar to the activity level data.

INTENSITY OF SYMPTOMS DATA

Treatment Group

In reviewing the results for the change in the intensity of EILP (FIGURE 3.6), the treatment group had a significant decrease in the amount of pain experienced with exercise from the Peak of pain preoperatively to the Present time (**Peak-Present Mean=5.15, S.D.=3.40, $p<.001$, 2 Tail**).

Control Group

The control group had a nonsignificant increase in the intensity of their leg symptoms over the same time period (**Peak-Present Mean=-0.85, S.D.=3.04, $.1>p>.05$, 2 Tail**).

Treatment vs. Control Group

The treatment group had a significant decrease in the intensity of symptoms when compared with the control group (**TREATMENT-CONTROL**) (**Peak-Present Mean=6.01, S.D.=.98, $p<.001$, 2 Tail**). The treatment group experienced a dramatic drop in the intensity of their symptoms over time, whereas the control group had a small increase.

INTENSITY OF ACTIVITY REQUIRED FOR SYMPTOMS DATA

Treatment Group

The treatment group had a significant increase in the intensity of exercise that they could do before developing leg pain over time after surgery (**Peak-Present Mean=-4.56, S.D.=3.63, $p<.001$, 2 Tail**) (FIGURE3.7).

Control Group

The control group did experience a significant decrease in the intensity of activity that was required to produce EILP (**Peak-Present Mean=0.67, S.D.=1.87, $.05>p>.02$, 2 Tail**).

Treatment vs. Control Group

The treatment group significantly increased the intensity of activity that they could perform pain-free when compared with the control group (**TREATMENT-CONTROL**) (**Peak-Present Mean=-5.24, S.D.=8.81, $p<.001$, 2 Tail**).

TREADMILL RESULTS

Twenty of 23 (87%) individuals in the treatment group compared with 7 of 23 (30%) in the control group developed leg pain while running on the treadmill (FIGURE 3.8). Thus, the vast majority of PAES patients are still having pain with progressive weight-bearing exercise. Roughly one third (7 of 23, or 30%) of control subjects volunteered leg symptoms while on the treadmill.

The times to develop leg pain for these individuals was very similar in both groups (**Treatment Mean=5.25 minutes, S.D.=3.19 Control Mean=6 minutes, S.D.=1 , $p>0.5$, 2 Tail**) (FIGURE3.9).

The reason for stopping the treadmill test was fatigue in 14 of 23 (61%) subjects in the treatment group and 22 of 23 (96%) control subjects (FIGURE 3.10). The two individuals who were in the "OTHER" category stopped the treadmill because of pregnancy and recent surgery.

Reviewing the total time spent on the treadmill, the treatment and control groups were quite similar (FIGURE 3.11). The control group continued with the progressive protocol for a longer period of time than the treatment group, although this was not significant (**Treatment Mean=8.7 minutes, S.D.=1.83** **Control Mean=9.8 minutes, S.D.=2.7, .2>p>.1, 2 Tail**)

DUPLEX ULTRASONOGRAPHY RESULTS

FIGURE 3.12, PREOP AND FOLLOW-UP DUPLEX RESULTS FOR ALL OPERATIVE LIMBS WITH PAES

The simple evaluation of preoperative and postoperative Duplex results showed that in general, there was a higher degree of entrapment in the preoperative evaluations than in the postoperative ones (FIGURE 3.12). However, 14 of 38 (37%) postoperative limbs had either a significant flow reduction or an occlusion.

DUPLEX / CLINICAL CORRELATION DATA

TABLE 3.4 PURPOSE: TO DETERMINE WHETHER THERE IS A RELATIONSHIP BETWEEN THE DEGREE OF ENTRAPMENT EVIDENT ON DUPLEX ULTRASONOGRAPHY AND A REDUCTION IN LEG SYMPTOMS AFTER SURGERY.

The treatment group was divided into 2 groups:

- 1) Subjects who had >50% reduction in the intensity of their symptoms
from peak (preop) to the present time (follow-up)
- 2) Subjects who had <50% reduction in the intensity of their symptoms
from peak (preop) to the present time (follow-up)

These groups were then analyzed to see if there was a decrease in the degree of entrapment on Duplex exam from peak (preop) to the present time (follow-up).

		<u>>50% DECREASE IN SYMPTOMS</u>		
		YES	NO	
<u>DECREASE</u>	YES	18	4	22
<u>ENTRAPMENT</u>				
<u>ON DUPLEX</u>	NO	9	5	14
		27	9	

Chi-Square analysis revealed that there was not a significant relationship between a decrease in entrapment on Duplex and a reduction in leg symptoms after surgery ($0.9 > p > 0.1$, 2 tail). However, when individuals with compartment surgery were excluded from the analysis, the relationship was found to be significant ($0.025 > p > 0.01$, 2 tail).

TABLE 3.5 PURPOSE: TO DETERMINE WHETHER THERE IS A RELATIONSHIP BETWEEN THE DEGREE OF ENTRAPMENT EVIDENT ON DUPLEX ULTRASONOGRAPHY AND AN INCREASE IN THE INTENSITY OF ACTIVITY POSSIBLE BEFORE SYMPTOM ONSET AFTER SURGERY.

The treatment group was divided into 2 groups:

- 1) Subjects who had a >50% increase in the intensity of activity possible before symptom onset from peak (preop) to the present time (follow-up) **OR** the absence of symptoms with severe exertion at the present time (follow-up).
- 2) Subjects who had a <50% increase in the amount of activity possible before symptom onset from peak (preop) to the present time (follow-up)

These groups were then analyzed to see if there was a decrease in the degree of entrapment on Duplex exam from peak (preop) to the present time (follow-up).

		<u>>50% INCREASE IN ACTIVITY</u>		
		YES	NO	
<u>DECREASE</u>	YES	16	6	22
<u>ENTRAPMENT</u>				
<u>ON DUPLEX</u>	NO	6	8	14
		22	14	

Chi-Square analysis revealed that there was not a significant relationship between a decrease in entrapment on Duplex and an increase in the intensity of activity before symptom development after surgery ($0.1 > p > 0.05$, 2 tail). Additionally, when individuals with compartment surgery were excluded from the analysis, again the relationship was found to be nonsignificant ($0.1 > p > 0.05$, 2 tail).

**TABLE 3.6 PURPOSE: TO DETERMINE WHETHER THERE IS A RELATIONSHIP
BETWEEN THE DEGREE OF ENTRAPMENT EVIDENT ON PRE-
OPERATIVE DUPLEX EXAMINATION AND A REDUCTION IN LEG
SYMPTOMS AFTER SURGERY.**

		<u>>50% DECREASE IN INTENSITY OF PAIN</u>		
		YES	NO	
<u>PREOP</u>	OCCLUSION	16	7	23
<u>DUPLEX</u>	SIG FLOW RED	9	3	12
		22	14	

Chi-Square analysis revealed that there was not a significant relationship between the Preop Duplex examination and a >50% improvement in pain relief in the postoperative period (0.9>p>0.1, 2 tail)

Additionally, when individuals with compartment surgery were excluded from the analysis, again the relationship was found to be nonsignificant (0.9>p>0.1, 2 tail)

TABLE 3.7 PURPOSE: TO DETERMINE WHETHER THERE IS A RELATIONSHIP BETWEEN THE DEGREE OF ENTRAPMENT EVIDENT ON PRE-OPERATIVE DUPLEX EXAMINATION AND AN INCREASE IN THE INTENSITY OF ACTIVITY POSSIBLE BEFORE SYMPTOM ONSET AFTER SURGERY.

		<u>>50% INCREASE IN ACTIVITY</u>		
		<u>YES</u>	<u>NO</u>	
<u>PREOP</u>	OCCLUSION	14	9	23
<u>DUPLEX</u>	SIG FLOW RED	7	6	12
		22	14	

Chi-Square analysis revealed that the preop Duplex examination was unable to predict which patient's will have a >50% improvement in the intensity of activity or no pain with activity in the postoperative period ($0.9 > p > 0.1$, 2 tail).

Additionally, when individuals with compartment surgery were excluded from the analysis, again the relationship was found to be nonsignificant ($0.9 > p > 0.1$, 2 tail).

PATIENT SATISFACTION RESULTS

The evaluation of patient satisfaction with a number of different issues relating to PAES surgery was recorded in FIGURE 3.13. Fourteen of 23 (61%) individuals rated their overall satisfaction with PAES surgery as good or excellent. Similar results were noted for the four questions.

The PAES patients were divided in to two groups, based on whether they rated their overall satisfaction with PAES surgery as poor/fair or good/excellent. None of the factors that were looked at to determine prognosis for patient satisfaction were significantly different ($p < .05$, 2 Tail) between the excellent/good and fair/poor groups (FIGURE 3.14). The major factor responsible for this was the small numbers available for statistical analysis in the two groups. While the fair/poor group were older (mean age 25, S.D. 9.75) than the excellent/good group (mean age 20.4, S.D. 6.64) at the time of diagnosis this did not reach significance ($p > .05$). Also, individuals in the excellent/good group (mean number of weeks 3.6, S.D. 2.94) returned to work/school more than twice as late as individuals with the poorer satisfaction (mean number of weeks 1.6, S.D. .74) but again because of small numbers, this was not significant ($p > .05$).

DISCUSSION

DISCUSSION OF GENERAL RESULTS

The study evaluated 23 out of a possible 29 individuals (79%) who had underwent PAES surgery. Of the 6 individuals who were eligible for inclusion in the study but did not participate, the 3 individual cases not involving geography as a reason for not participating will be discussed. First of all, the death of a healthy young individual from an elective procedure should serve notice that surgery, although generally well-tolerated by the majority of patients, is an intervention that should be carefully considered by all parties involved. Secondly, of the two individuals who refused to participate, one simply could not find the time and the other was frustrated by the medical profession and its inability to help him with his problems. This unfortunate 32 year old male had extensive investigation and many consultations for his exercise-induced leg pain after receiving no relief of his symptoms with surgery.

Seventy-eight percent of the study subjects were females. This female predominance has not been reported before in the literature. Most authors detailing cases of PAES have described up to a 90% male predominance (1,3,6,18,41). This may be explained in part by the contribution of a number of case series' from military populations to the PAES literature, which would likely have a marked male predominance.

It should be noted that adolescent female dancers may be at higher risk for developing PAES. In this series, four such individuals described dancing as their primary activity. It was hypothesized that the repetitive and prolonged plantarflexion positions and frequent jumping required in ballet in particular, may have caused the lower extremity symptoms. This population of PAES patients has contributed to the predominance of females in our series.

The mean age for the study subjects of 24.9 years compares quite favourably with what appears in the literature, although it is the youngest group of substantial size that has been reported. Collins *et al.* (16) found an average age of 27 years, Murray *et al.* (1) in a review of existing literature found a mean age at presentation of 28 years, and Ikeda *et al.* (25) described an average age of 25 years. Zund *et al.* (13)

determined a mean age of 38.5 years at the time of diagnosis. It must be acknowledged that the inclusion criteria for the study define an age less than 40 years at the time of surgery.

Similar to the mean age of 21 years calculated by Murray *et al.*, the mean age of females at the time of diagnosis with PAES was 22.3 years, significantly younger than that of their male counterparts at 34.2 years.

In our series 20 (87%) individuals had bilateral surgery. Twenty-one (91%) individuals were found to have bilateral PAES. This is more than that presented by other authors in the literature to date (3,6,7,16). The incidence of bilateral PAES ranges from 18% as observed by di Marzo *et al.* (6), to 67% as reported by Collins *et al.* (16). It should be noted that in this series as well as that reported by Collins included both symptomatic and asymptomatic limbs in the total. Other authors (6,7,18) included only symptomatic individuals. What is even more disparate in this study is that 18 of 23 (86%) individuals had bilateral symptoms; whereas in Collins' study only 3 of 12 (24%) patients had symptoms in both legs. The reason for this is unknown. There may be a difference in what is classified as unilateral and bilateral symptoms between authors, as individuals with bilateral symptoms may have a leg whose symptoms were of lesser intensity than the other and may have not been considered significant. For the purpose of this study, individuals who volunteered that they were experiencing exercise-induced leg pain in both legs were classified as having bilateral symptoms, no matter what the intensity. Additionally, the numbers in Collins' series were quite small, which could have skewed the results.

A mean time from onset of symptoms to diagnosis of 25 months or roughly 2.1 years was calculated. Zund *et al.* (13) reported a delay of 5 years from the occurrence of first symptoms to the diagnosis (18). Ikeda *et al.* (25) described the duration of symptoms before admission, and found a range from 20 days to 16 months for their 19 patients. Collins *et al.* (16) calculated an average duration of symptoms of 13 months, with a range from 2 months to 3 years. He also made the point that most patients had visited many clinics before the diagnosis was established. The value from this study falls in between those listed above. Many of the patients in this case series claimed that health care practitioners were often at odds in coming up with specific diagnoses and their discomfort was attributed to "shin splints" and not taken seriously. Additionally, health care professionals may be reluctant to ascribe a vascular etiology to lower limb

symptoms in healthy, active, young individuals. Clearly, there is a need for education of medical practitioners about this condition. Alternatively, the long length of time before diagnosis may in part be due to the patients who often consider the pain that they have been experiencing as benign "shin splints" and do not seek medical attention until the severity of symptoms begins to significantly interfere with their activities.

A mean follow up time of 2.5 years was determined in the study. There is a large range in the length of follow-up for studies in the literature. Ranging from the 1 month postoperative treadmill test by Collins *et al.* (16) (no formal calculation of the length of follow-up was calculated) to the 7 year and 2 month follow-up by Zund *et al.* (13).

The length of time from the surgery to return to work or school was a relatively short 2.8 weeks. However, the time to return to provocative activity was approximately 3 times longer at 8.8 weeks. Unfortunately, there is no literature to compare these results to. This information will be useful in counselling patients undergoing PAES surgery in the future.

A number of classification schemes to describe PAES have evolved (15,20,21,22,23). As none of the classification schemes have a bearing on clinical diagnosis, therapy or prognosis, it may be best to simply describe the anatomic findings at surgery. Moreover, the anatomic description is subjective. In this series one surgeon described the same anatomic finding in all patients under his care. This specific finding was not described by the other two surgeons.

Only 2 individuals in the study underwent reconstructive procedures. This is a significantly smaller proportion than has been described in the literature. Di Marzo *et al.* (7) reported that 12 of 31 (39%) cases involved a reconstructive arterial procedure. Schurmann *et al.* (39), performed reconstructive surgery on all PAES patients. In a review of the Japanese literature in 1981 by Ikeda *et al.* (25), 22 of 24 (91.7%) limbs had vascular reconstructive procedures. In this series only 4 out of 43 (9%) limbs operated on for PAES had reconstructive procedures done.

Why the marked difference in the frequency of vascular reconstructive procedures between this series and those of other authors? Certainly, it must be acknowledged that there will be different surgical approaches among surgeons for similar clinical problems. It may be that the surgeons in this series may be more conservative when it comes to aggressive arterial reconstruction. However, it is possible that the patients who are on average younger than individuals in other series' (in part due to the exclusion of individuals over 40 years of age in this study) are suffering a milder form of the disease, or alternatively, an earlier stage of the disease. A comparison of preoperative angiographic findings may be able to shed some light on this subject. Unfortunately, only some of the authors described the preoperative angiographic findings in their patients. Di Marzo *et al.* in his series of 31 cases, described arterial occlusions in 8, stenoses in 8 and aneurysms in 2 limbs with views taken when the ankle was in a neutral position. In Collins' series (16) there was 4 occlusions evident on angiography. In our series there was no angiographic abnormalities with views done in a neutral position. These results suggest that the patients in other series' had more extensive arterial disease at the time of diagnosis than our patients. It may be that the patients in this series are experiencing a milder form of the disease when they begin to develop symptoms because they are challenging themselves regularly with athletic activity. It is tempting to conclude that these subjects have milder disease because they are younger and use this as evidence to support the premise that untreated PAES leads to progressive arterial damage. However, the retrospective study design does not allow one to make such conclusions. One interesting characteristic of the individuals who eventually underwent reconstructive procedures was that both were smokers. It is possible to hypothesize that smoking could accelerate the intrinsic arterial damage that is believed to occur with this problem, leading to reconstructive surgery.

In TABLE 3.2 the complications of PAES surgery are listed. A sural neuropathy developed in 1 individual who described postoperative numbness. For this individual it was a nuisance more than a disability and the numbness decreased in intensity over time. One female developed hypertrophic scarring of her surgical incisions. Of note, the case of hypertrophic scarring occurred with an S-shaped popliteal incision. In this series, a horizontal incision was used in 21 of 23 individuals with simple PAE releases. One case of a popliteal fossa hematoma developed one week after surgery and was drained without further complication in the emergency department.

It has not been noted before in the english language PAES literature of the co-existence of PAES and chronic compartment syndromes (CCS). However, it has been recognized that CCS and PAES have very similar symptoms (45). Moreover, Allen *et al.* (45) reported on a case of PAES that was misdiagnosed as a CCS. In this series, 3 individuals that underwent fasciotomy for CCS in addition to their PAES surgery (TABLE 3.3). All individuals operated on for compartment syndromes had elevated compartment pressures. Two of the 3 individuals had inadequate relief of their symptoms post-fasciotomy, which led to investigation for PAES. The other patient experienced inadequate relief of symptoms post-PAES surgery and then subsequently underwent compartment surgery. The reason for this co-existence is not known, but it is interesting and needs to be studied further. One hypothesis regarding the pathophysiology of CCS with PAES is that chronic ischemia from PAES might lead to scarring in the compartments and altered blood flow that could bring about elevated compartment pressures with exercise. Alternatively, in these individuals there may be a single underlying disease process for the two problems that we are currently unaware of. Furthermore, it may simply be that the diagnostic tests for PAES and/or compartment syndromes have a high incidence of false positive results.

Two individuals were noted to have tibial stress fractures confirmed on bone scan. One (29 year old male) individual had recurrent stress fractures both in the preoperative and postoperative periods. The other (16 year old female) also had multiple stress fractures in the pre and postoperative period. Furthermore, this female also had CCS, with fasciotomy after PAES surgery. The above observations makes one wonder whether there is some relationship between these different causes of exercise-induced leg pain. Chronic ischemia of the leg musculature during exercise from PAES may cause muscle fatigue resulting in increased structural stress to bone and possibly a stress fracture. Clearly, research in this area would be valuable.

DISCUSSION OF MAIN RESULTS

DISCUSSION OF ACTIVITY LEVEL DATA

Even though active individuals are willing to seek medical advice regarding their EILP and undergo painful investigative and surgical procedures, it still did not change their activity level significantly (FIGURE 3.2). This is likely related to the passion that many people have for their activity and the unwillingness to give it up in the face of discomfort.

The combination of surgery and time cannot really be said to restore normal activity levels because they were never significantly decreased at the time of peak pain (the preoperative period of time). However, relative to a healthy control group these individuals suffered a relative decrease in their activity level from their presymptomatic to their current level .

It should be acknowledged that eleven out of 23 (48%) individuals were able to increase their activity in the follow-up period after PAES surgery over the level of activity prior to developing EILP. This compares quite favourably with the control group (13 of 23 (57%)). Furthermore, of all individuals who increased their activity level, all were able to return to their provocative activity.

The similar total time spent on the treadmill for treatment and control groups reinforce the view that the post-surgery activity level for PAES patients is not restricted because of persistent leg pain (FIGURE 3. 11).

The results for the reasons given for changes in activity levels over the time periods can be interpreted in a number of ways (FIGURE 3.3). One explanation is simply that over time, individuals with chronic EILP develop different reasons for changing their activity levels. In support of this hypothesis, the length of time for each of the time periods (**(1) Prior-Peak Mean=18.0 months, S.D.=17.20 (2) Peak-Present Mean=32.2 months, S.D.=19.81 (3) Prior-Present Mean=50.4 months, S.D.=29.75**) increased as the number of individuals who rated the contribution of leg pain as very

important decreased. Intuitively, this makes sense, as we know that the pain from PAES does not stop individuals from being active. It is reasonable to assume that other reasons would influence their changes in activity over longer periods of time.

DISCUSSION OF PERFORMANCE DATA

From the results it can be concluded that PAES decreases activity performance (FIGURE 3.4). Although individuals experienced an increase in performance over time after surgery, this did not bring them back to their premorbid performance levels. The control group increased its activity level over time. As might be expected, with the increase in activity in the control group, an increase in performance was observed. The treatment group did not change its activity level over time, but did experience a drop in performance. This suggests that PAES has a differential effect on performance.

More individuals felt that PAES was more important in contributing to their change in performance than to their change in activity over the time periods 1) Prior to Peak and 2) Peak to Present (FIGURE 3.5). Not surprisingly, patients who have experienced more dramatic decreases in performance than in activity level would rate PAES as the more important contributor to their decrease in performance than to their activity level.

This differential effect on performance is seen with other clinical conditions in sports medicine. Sports medicine patients, in particular more competitive or elite ones, often seek medical consultation because of problems that affect the quality of activity or performance but not necessarily the quantity.

DISCUSSION OF SYMPTOMS DATA

The results suggest that over time after surgery, individuals with PAES generally experience an improvement in the intensity of their exercise-induced leg symptoms (FIGURE 3.6). Furthermore, they are able to significantly increase the intensity of exercise that they can do before developing leg pain (FIGURE 3.7).

The improvement in leg symptoms may in part be due to the fact that the treatment group is less active now than they were in their premorbid state. The majority of individuals (87% in the treatment group vs. 30% in the control group) still develop leg pain while running as evidenced by the results from the treadmill run (FIGURE 3.8). For 35% (7 of 20) of these individuals with pain, the symptoms were severe enough to cause them to stop exercising (FIGURE 3.10). Thus in summary, the majority of individuals experience reduction but not resolution of their symptoms over time after surgery.

Why are there so many patients experiencing symptoms after surgery? First of all, the EILP may be due to another condition. It was noted in this study that individuals with PAES can have stress fractures and/or chronic compartment syndromes. The study participants were screened by a medical doctor for just such conditions. Realistically, invasive and expensive diagnostic procedures are necessary to definitively exclude these other diagnoses. Thus, it remains possible that the symptomatic individuals are experiencing pain from pathologies other than PAES. Secondly, the operation may have failed to release the entrapment of the artery, or alternatively scar tissue from the surgery might still be entrapping the artery. In support of this is the fourteen limbs that had evidence of either a significant flow reduction or occlusion on Duplex examination at follow-up (FIGURE 3.12). Thirdly, one might hypothesize that longstanding entrapment of the artery causing ischemia of the leg musculature might lead to permanent, irreversible damage in these structures. Lastly, a short popliteal artery may be a consequence of entrapment during the adolescent years of rapid growth. A congenitally entrapped artery may be growth retarded and therefore relatively shorter than an untrapped one. When stretched during activity, the relatively short artery may produce symptoms.

The increase in the intensity of activity required for symptom development was reflected in the similar times to develop leg pain for the treatment and control groups on the treadmill (FIGURE 3.9). Of note, in the treadmill protocol the grade did not increase until the 8 minute mark. The development of leg pain prior to this period of time would not be influenced by changes in gait related to the incline. At the 5-6 minute mark, the treadmill was moving at 8 km/h, a speed where virtually everyone was jogging. However, in the treatment group there was more variability in the times to develop leg pain (S.D.=3.19 vs. 1). Some individuals in the treatment group developed symptoms at a treadmill speeds as low as 4,5 and 6 km/h. Interestingly, not everyone who developed leg pain at the slow treadmill speeds had to stop the test because of leg pain.

An intriguing result was the increase in the intensity of leg symptoms (FIGURE 3.6) and the decreased activity tolerance (FIGURE 3.7) noted in the control group. One might hypothesize that because the control group increased their activity level and performance over this period of time, that they were at greater risk for "overuse" syndromes manifesting EILP.

The results must not be misinterpreted to mean that the surgery improves the exercise-induced leg pain. This question can only be answered by following an untreated group with PAES in a randomized trial. Unfortunately, this has never been done and it is unlikely to be done in the future, given that the standard of care has been surgical management for confirmed PAES. At the present time it is not known whether time itself or the surgery that brought about the observed benefits. Unfortunately, the relative contribution of these two factors to the subjective improvement cannot be evaluated. However, this information will be useful to counsel patients in the future.

DISCUSSION OF DUPLEX ULTRASONOGRAPHY RESULTS

The results from the Duplex evaluation were enlightening. While the simple evaluation of preoperative and postoperative Duplex results showed that in general, there was a higher degree of entrapment in the preoperative evaluations than in the postoperative ones (FIGURE 3.12), fourteen limbs had evidence of either a significant flow reduction or occlusion at follow-up examination.

The Duplex / Clinical Correlation Data was disappointing. A decrease in the degree of entrapment on Duplex after surgery was not associated with either an improvement in leg symptoms (TABLE 3.4) or increased tolerance for exercise (TABLE 3.5). Similarly, preoperative Duplex examination was not able to predict postoperative change in the same parameters (TABLES 3.6,3.7). There was one significant result (TABLE 3.4), comparing an improvement in Duplex entrapment with an improvement in leg symptoms with exercise when excluding individuals who had undergone compartment surgery. The most likely explanation for this is a false positive result because of multiple analyses on the same data.

Why do the results from the Duplex not correlate well with what is happening clinically? One point that has been raised by other investigators is that flow disturbances in the popliteal artery may be physiologic (43,44). If entrapment of the popliteal artery is expected in normal individuals, it would not be surprising to find both a lack of clinical correlation and postoperative Duplex examinations that show persistent entrapment. But what constitutes a normal and an abnormal test if a variable degree of entrapment and possibly occlusion can be expected in normal individuals? In this study the upper limit of acceptability to divide normal from tests with significant flow reduction (>2.5 times normal arterial flow speed) was based on expert opinion rather than science. It must be appreciated that this is a subjective test, not only from its evaluation, but also from the subject's participation. As each subject is required to forcefully plantar flex his/her foot to elicit any entrapment of the artery, the degree of effort put into this process is obviously variable. Many Duplex evaluations do not demonstrate entrapment until intense plantarflexion is undertaken by the patient. Individuals who do not exert themselves fully with this evaluation may be classified as normal based on their lack of entrapment. Furthermore, there is the added technical problems of imaging a popliteal artery that moves with active plantarflexion. If the technician slipped of the artery with

the Duplex probe, a loss of the arterial signal would occur and an erroneous interpretation of artery occlusion might be made.

One thing is apparent, Duplex Ultrasonography for PAES is controversial. From the results in this study, Duplex evaluation does not appear to offer information that would of help in determining prognosis for individuals suspected of having PAES and those who have had surgery for PAES. Standardization of protocols for testing and evaluation need to be implemented.

DISCUSSION OF PATIENT SATISFACTION RESULTS

Sixty-one percent of individuals rated their satisfaction with PAES surgery as good or excellent (FIGURE 3.13). This contrasts with results from Collins' series (16), where all results were classified as being either good or excellent (7 excellent, 3 good). The results from this study are more similar to those of Schurmann *et al.* (39), in which 6 of 11 (54.5%) individuals with PAES surgery were judged to have excellent results. Of note, one individual in his series had an excellent result in one leg and required a bypass procedure 6.5 years post-operative in the other leg. Di Marzo *et al.* (7) described a 94.4% patency rate after surgery in their myotomy group. However, it was not mentioned whether these individuals had persistent symptoms after surgery. What also must be acknowledged is that these results are the patients' evaluation of the surgery. Whereas in the other studies described, the results are from the author's point of view.

Why are the results from surgery in this study different from others described in the literature? Certainly, having the patients evaluate the operation may either eliminate or create some biases. The possibility of an investigator bias, whereby investigators either consciously or subconsciously inflate the benefit of their intervention is eliminated with patient evaluation. However, patients may have unreasonable expectations of what surgery can do for them. It is possible that the physical demands of the patients in this series who are all athletic, may be higher than those in other series'. Thus, although the satisfaction with the results may be good for individuals with low physical demands, the more active individuals may be unhappy with symptoms at high physical intensities. Furthermore, in this study individuals were evaluated at three points in time and a control group was used. Other studies in the literature did not have such design features, and therefore may have observed different results because of known and unknown biases.

None of the factors that were looked at to determine prognosis for patient satisfaction were significantly different between the excellent/good and fair/poor groups (FIGURE 3.14). The major factor responsible for this is the small numbers available for statistical analysis in the two groups. An interesting observation

was that the group with higher satisfaction had a greater prevalence of fascial bands altering the anatomy of the popliteal artery than the less satisfied group (5 vs.1). One might hypothesize that the fascial bands are an anatomic structure that can be definitively managed with surgery; whereas removal of muscle and altering the course of the artery at surgery may be less predictable in permanently decreasing the entrapment of the artery.

Another observation was the higher incidence of smoking in individuals in the fair/poor results group (4 vs. 1). The only smoker in the good/excellent group ended up having bypasses on both limbs for acute ischemia. Thus, one might question whether in fact he might be better off in the fair/poor group, which would further strengthen the association. Schurmann *et al.* (39) recorded risk factors for atherosclerosis in their subjects. However, of the 4 individuals they described as smokers, 3 had excellent results and one was described as having pain in the foot while running. It is possible that individuals with entrapment of their popliteal artery may be at risk for poor results because of their smoking. Perhaps the damage to the artery from entrapment is accelerated by individuals who smoke. On the other hand, this behaviour may simply be a marker for other characteristics that are at the present time unknowingly affect the results of surgery.

LIMITATIONS OF THE STUDY

There are a number of biases that are inherent with this study design.

1) Sampling biases:

Only a subset of individuals who underwent PAES surgery were included in the study. The study was limited to those individuals under 40 years of age who had been referred to sports medicine physicians. Thus, the study results will only be generalizable to the patients of a referral-based sports medicine physician. The PAES patients seen by sports medicine physicians are often in their teens through thirties, healthy, athletic and only develop symptoms during exercise. This patient subgroup is different in demographics and presentation from the subgroup of patients who make their way to surgery because of the need for emergency limb revascularization. The latter subgroup of patients present with severe claudication and signs of ischemia at rest or with minimal exercise. Often only at the time of angiography or at surgery are these patients suspected of having PAES. These patients may be in their forties and fifties or older, inactive and have risk factors for generalized atherosclerosis. Obviously, this subset of patients is different from that routinely seen by the sports medicine physician. A study to accommodate both of these subgroups would increase external validity, but at the expense of internal validity. This study design maximizes internal validity but its generalizability suffers.

Other sampling biases:

Referral filter bias, Centripetal bias, Diagnostic suspicion bias

2) Treatment biases:

The majority of subjects eligible for the study have been operated on by one surgeon. Results of this study may be better than those obtained by surgeons with less experience in the surgical management of PAES.

3) Outcome biases:

A large recall bias must be acknowledged in determining retrospective activity data for a period of time of up to 6 years on the questionnaire. However, contributory information from the patient's chart may have helped to decrease this. Additionally, the possibility of subjects altering their questionnaire responses in the direction they perceive desired by the investigator (obsequiousness bias) might have been an important factor. Although a past history for other causes of exercise-induced leg pain was recorded, undiagnosed causes for exercise-induced leg pain may have skewed the results. For example, if at the time of follow-up a patient was experiencing symptoms from CCS and not PAES, the symptoms would still be attributed to the PAES. Lastly, note must be made that although the interviewer asked structured, neutral questions, he was not blinded to the process. Similarly, there was no blinding in the examination of results except for the Duplex evaluation.

SUMMARY

The main purpose of this study was to determine the prognosis after Popliteal Artery Entrapment Syndrome (PAES) surgery for young, active individuals. The hypothesis was that after PAES surgery, full restoration of activity level and sport performance with improvements in exercise-induced leg symptoms and activity tolerance occurs when the surgery is carried out at an early stage of the condition.

Twenty-three subjects all having had PAES surgery were interviewed and visual analogue scales were used to record data on: 1) activity levels, 2) performance levels, 3) intensity of leg symptoms and 4) intensity of activity tolerated. The above information was evaluated at three different times: 1) prior to the development of symptoms, 2) at the peak of symptoms (preop), and 3) at the present time (follow-up). Each individual underwent a medical evaluation as well as Duplex Ultrasonography of the affected popliteal artery (ies). Lastly, the subjects performed a progressive treadmill test. Control subjects that were matched for age, sex and education level were recruited for comparison.

Results showed that the treatment group's activity level did not change significantly over the time periods. However, the treatment group experienced a significant decrease in its activity from its premorbid level to its current level when compared with the control group ($p < .001$). Reviewing the performance data, it was evident that the development of PAES caused a significant drop in activity performance for affected individuals ($p < .001$). Furthermore, the performance did not return to presymptomatic levels after surgery. This result was observed when the treatment group was evaluated on its own ($.02 > p > .05$) and also when compared with the control group ($.01 > p > .001$).

The combination of PAES surgery and time did bring about a significant decrease in leg symptoms while exercising when compared with the control group ($p < .001$). Similarly, an increase in the intensity of activity possible before symptom onset was noted after surgery when compared with the control group ($p < .001$).

CONCLUSIONS

1. That individuals with PAES do not significantly change their activity levels because of their symptoms. They persist with activities despite having exercise-induced leg pain. This may be related to becoming accustomed to experiencing pain or possibly due to the passion that many individuals feel for their activities and the reluctance of them to decrease their activity level.
2. PAES has a dramatic effect on the performance of activities. This drop in performance noted with the onset of symptoms is not made up over time after surgery.
3. Over time after surgery a significant decrease in the intensity of leg symptoms was noted. However, 87% of individuals still volunteered symptoms of leg discomfort while on the treadmill.
4. Individuals experienced a tolerance for higher intensity levels of activity without pain over time after surgery. This observation was strengthened objectively by the fact that they did not differ significantly from the control group in the length of time that they continued with the progressive treadmill protocol. Additionally, the treatment and control group were similar in the amount of time spent on the treadmill before developing leg symptoms.
5. There are no clear reasons why individuals differ in their prognosis after PAES surgery. The impact of age, sex, smoking status and specific surgical anatomy need to be looked at prospectively in the future.
6. Duplex Ultrasonography was not found to be a useful tool to determine the prognosis for individuals with PAES. Further research with Duplex is necessary to fully define its role in the diagnosis of PAES.
7. This research has not added any new information to the risks of untreated PAES. Thus, based entirely on previous retrospective studies, surgery for PAES is still indicated to prevent the arterial damage that is believed to be the natural history of progression of the syndrome.

RECOMMENDATIONS

1. A prospective, randomized study is needed to determine whether the outcomes noted above are due to the passage of time after surgery, or to the surgery itself. Among other things, a study of this design would be able to establish whether patients with untreated PAES are at risk for developing the vascular complications that have been touted in the literature (7,16). Unfortunately, this is unlikely to happen given the incidence of the disease and the length of follow-up required.
2. A prospective study would be more methodologically sound than the retrospective study just undertaken. It would be a more realistic research initiative than the randomized trial outlined in 1.
3. More research needs to be done in the area of Duplex Ultrasonography. The study done by Akkersdijk *et al.* (43) needs to be repeated with athletic, asymptomatic individuals. The addition of some other instrument to measure tissue oxygenation may be useful to further quantify popliteal artery entrapment. Protocols involving patient position, the amount of force applied in ankle plantarflexion, the use of distal arteries and guidelines for classifying different levels of entrapment need to be evaluated.
4. A closer look needs to be undertaken regarding the co-existence of different causes of exercise-induced leg pain. The observation that Chronic Compartment Syndrome, PAES and recurrent stress fractures can occur in individuals begs further investigation, possibly at a basic science level.

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APPENDIX I

REVIEW OF THE LITERATURE ON PAES

History

Anderson Stuart, a medical student in Edinburgh, first described an abnormal course of the popliteal artery in 1879, when he dissected a limb amputated for gangrene (1,2). In 1925, Charnbardel-Dubreuil described a variant in which an accessory slip of the medial head of gastrocnemius, arising from the femur, separated the popliteal artery from its accompanying vein (3). The first clinical case was described by Hamming in 1959, in which a 12 year-old boy experienced calf pain and foot paresthesia with exercise (4). When surgically explored, the popliteal artery was found to have an abnormal course medial to the medial head of gastrocnemius. The term "popliteal artery entrapment syndrome" was first used by Love and Whelan in 1965, when describing two cases of isolated popliteal occlusion in fit young men (5).

Etiology and Epidemiology

The exact etiology of popliteal entrapment is unknown, but has an embryological basis related to the development of both the musculature and the arterial supply of the lower limb (6).

During embryonic life, the medial head of gastrocnemius migrates medially and cranially. It is with this migration that the popliteal artery can be caught and swept medially with it (7). Alternatively, muscular migration may be incomplete (8).

Developmental anomalies of the popliteal artery could account for the the rare instances of entrapment caused by the popliteus muscle, when persistence of the ventral component of artery occurs (9). It should be noted that the anomalies are often complex and often do not allow a clear embryological explanation (7).

Another mechanism has been proposed in which muscle contraction (active plantarflexion) or passive dorsiflexion of the foot compresses the artery between muscle and the underlying bone. This offers a better explanation why the syndrome is commonly seen in healthy, young athletes who hypertrophy their gastrocnemius muscles through vigorous training.

The incidence of PAES is not known, but is likely to be more common than currently thought. In a selected series of 86 post-mortem examinations of symptomatic vascular patients, Gibson *et al.* found three cases of anatomic abnormality for an incidence of 3.5% (10). In the European literature, (11) showed that 1.4% of occlusions of the popliteal artery also had an entrapment of the artery. Similarly, Brunner (12) calculated an incidence of popliteal entrapment of 4.9% in chronic obstructions of the popliteal artery. In summary, there is no good indication of the incidence of PAES in the general population.

PAES appears to be most common in young athletic male patients (13,14,15). However, the finding that the condition is more common in males may be due to the over representation of articles from military hospitals who treat a predominantly male population (16), or possibly due to the fact that on average, males tend to be more active than females and would thus be more likely to suffer symptoms. In a recent large series by Zund (13), 17 of 20 (85%) patients were male with an average age of onset of first symptoms at 33.5 years of age. Similarly, a case series put together by di Marzo *et al.* in 1990 (7) found that 18 males (78%) and 5 females had been treated surgically for PAES with a mean age of 34.7 years.

PAES has been found to occur bilaterally in approximately 25% of cases (7,17,6). However, Collins *et al.* in 1989 (18) found bilateral popliteal entrapment in 8 of 12 patients for an incidence of 67%. Only 3 of 12 (25%) patients had symptoms in both legs. The other 5 patients were found to have bilateral entrapment

with only unilateral symptoms. They reasoned that studying the asymptomatic limbs, which had not been done before, likely accounted for the higher incidence of bilateral lesions found in their series. There have been sporadic case reports of a familial tendency in PAES (4,19).

Classification

There are a number of different classification schemes to describe PAES.

Insua was the first to devise a classification system based on 17 previously reported cases and 2 which he had managed (20). His system utilized 4 groupings: types 1, 1a, 2 and 2a based on 2 main types of abnormality, with variations based on the course of the popliteal artery in relation to the medial head of the gastrocnemius muscle.

Delaney (21) described a simpler classification; initially of three main types, but he later added a fourth type (Figure 2.1) (15). With a type 1 abnormality, the artery follows the classic aberrant course, looping medially to and then beneath the medial head of gastrocnemius. In a type 2 abnormality, the artery lies in its normal position but is compressed by the medial head of gastrocnemius which arises more laterally on the intercondylar area rather than the medial epicondyle. In a type 3 abnormality, the medial head of gastrocnemius has an additional musculotendinous slip on its lateral side arising from the intercondylar area compressing the popliteal artery as it runs across it to join the main muscle bulk. In a type 4 abnormality, the popliteal artery is compressed as it passes beneath the popliteus muscle as well as the medial head of gastrocnemius. More recently, those cases in which fibrous rather than muscular bands tether the artery have also been included in the type 4 classification. In 1979, Rich and colleagues have added a fifth group including those cases in which the vein as well as the artery is entrapped (22).

Ferrero *et al.* have described a complex classification in which more than 10 different types of abnormalities are described (23).

Despite the classification systems there exists anatomical variants that do not fit into a defined category. Additionally, types 2, 3 and 4 from Delaney's classification system are in fact all variations in the normal relationship between the popliteal artery and its surrounding musculature; and are subject to interpreter error. Moreover, the classifications have no bearing on clinical diagnosis, therapy or prognosis. Thus it may make the most sense to just describe the anatomical findings as is, and not try to classify the anomaly.

Figure II.1: Classification of Popliteal Artery Entrapment Syndrome (From Rich NM, Collins GJ, McDonald PT et al. : Popliteal vascular entrapment: Its increasing interest. Arch Surg 114:1382, 1979)

Pathology

PAES is believed to be a progressive condition and the pathology seems to correlate well with the degree of entrapment and symptomatology (6). The end point is thought to be arterial thrombosis and embolization. Repeated extrinsic arterial compression from entrapment of the artery causes micro trauma to the arterial wall, leading to premature intrinsic atherosclerosis and/or thrombus formation. The progression of local disease leads to intraluminal stenosis and the resulting turbulence causes poststenotic dilatation and aneurysm formation (6). The development of collateral vessels can occur with these chronic changes. Acute ischemia may result from occlusion of the diseased vessel or thrombosis within an aneurysm. Additionally, distal embolization from a mural thrombus or from the wall of an aneurysm to the tibial vessels and the foot may precipitate severe ischemia (24).

Histologically, there is fibrous intimal thickening, with disruption of the internal elastic lamina, destruction of smooth muscle and proliferation of connective tissue (25). Abnormal bundles of longitudinal smooth muscle adjacent to normal circular muscle has been reported (25).

Clinical Features

The clinical features of PAES relate to the degree of disease within the popliteal artery. In cases studied to date, patients are often young individuals involved in either military service or sports. Both groups participate in strenuous physical exertion leading to a high degree of muscle development which may unmask occult pathology.

Most individuals (90%) present with claudication (6). Claudication is characterized by the absence of pain in a limb at rest and the onset of pain in the limb when a fixed work level is achieved. The fixed work level is determined by the degree of arterial compromise in the affected limb. Additionally, there will be a disappearance of symptoms after a brief period of rest. In PAES, claudication occurs occasionally with walking and not running (26,27). This is believed to be due to the more prolonged contraction of the gastrocnemius muscle with walking.

Roughly 10% of patients with PAES present with signs and symptoms of either acute or chronic limb ischemia. These include paresthesias, discolouration of the foot and toes, temperature change, rest pain and tissue necrosis (28). The lack of physical signs of diffuse acute or chronic ischemia is an important differentiating feature from those individuals with generalized atherosclerosis (16). Individuals with PAES are often free of atherosclerotic risk factors and tend to present at a young age.

The physical examination in individuals suspected of having PAES is often normal at rest. However, the popliteal, posterior tibial and dorsalis pedis pulses should be carefully palpated to determine whether any reduction in pulse volume or any asymmetry between limbs exists. The pulses should be palpated with the ankle in passive dorsiflexion and in active plantarflexion with the knee extended. Pulse deficit in these provocative positions has been considered pathognomonic (29) of PAES, but similar findings have been described in normal individuals (30).

If the condition had progressed to aneurysm formation, a pulsatile mass may be present in the popliteal fossa (29,31). Additionally, venous as well as arterial entrapment has been reported in the literature (7,30,31,32). This variant of PAES may present with exercise-induced leg swelling.

It is important to note that when a history compatible with PAES exists, vascular laboratory examination is essential to rule out the diagnosis.

Investigation

The diagnosis of PAES can be established with the careful selection of diagnostic studies. Non invasive tests have been advocated as useful screening tests for individuals with a clinical picture suggestive of PAES.

Often, the investigation will start with resting blood pressures of the posterior tibial and dorsalis pedis pulse in the foot via Doppler ultrasonography. Doppler ultrasonography involves measuring the shift in frequency of a continuous ultrasonic wave proportional to the blood flow velocity in underlying vessels. It is used to record lower limb blood pressures and to screen for occlusive peripheral vascular disease as will be outlined below.

A resting ankle / brachial index (ABI) of blood pressure is calculated to identify individuals with possible fixed, occlusive arterial lesions. In patients with normal ABI's (>1), exercise treadmill testing is then performed as described by MacDonald *et al.* (30). The patients continue with the progressive protocol until lower limb symptoms stop them, or until they finish the end of the test. Immediately post-exercise, the patients have their ABI's repeated, with ABI's < 1 indicating exercise-induced vascular insufficiency.

Continuous Wave (CW) Doppler ultrasonography of the posterior tibial artery can be carried out in a neutral position and during passive dorsiflexion and active plantarflexion of the ankle. If the normal triphasic pulse signal is reduced or disappears, the patient may have PAES, and investigators have suggested sending these individuals for duplex scanning (7). However, it should be noted that Doppler ultrasonographic studies of pulse presence in provocative positions can also be misleading, with pulse disappearance being demonstrated in apparently normal, asymptomatic students and athletes (7).

Duplex ultrasound combines B-mode ultrasonographic images with a range-gated pulsed-Doppler analysis of flowing blood at each point in the image. Thus, Duplex combines the anatomic detail of B mode ultrasound with the quantitative and qualitative analysis of arterial flow of Doppler ultrasound. This allows direct visualization of the popliteal artery as it is compressed, with simultaneous monitoring of arterial blood

flow. Duplex scanning has been used successfully in many different vascular territories to diagnose arterial narrowing and occlusion. A recent study has calculated a sensitivity of 94.2% and a specificity of 98.6% for the detection of arterial occlusion in the popliteal artery (33). However, the average age of patients in this study was 70 years and all subjects had severe peripheral vascular disease. Generalizing the results of this study to PAES patients is likely not valid. There have been no studies that have rigorously evaluated the usefulness of Duplex in diagnosing PAES. Clinicians managing PAES have been impressed with it as a screening tool. A review by di Marzo praised Duplex scanning as a simple non invasive procedure that should be used routinely in the evaluation of individuals suspected of having PAES (34). In his series, individuals with constant and significant (50% or greater) reduction of the velocity wave forms during provocative testing were considered to have a positive result. Di Marzo recommended arteriography to confirm the diagnosis if the CW Doppler and the Duplex scanning suggested arterial entrapment. However, a recent paper by Akkersdijk *et al.* (43) has called in to question whether compression of the popliteal artery by active plantar flexion of the foot is a physiologic phenomenon. He used 16 healthy volunteers and found that in 72% of volunteers, compression of the popliteal artery is evident during active plantar flexion. Peak systolic flow velocities were used to categorize the degree of entrapment of the popliteal artery.

Arteriography is an invasive procedure that involves taking roentgenograms (X rays) after injection of radiopaque material into the arterial segment of concern. This allows for precise anatomical definition of the arterial tree. Arteriography is well established as the gold standard for diagnosis of PAES. It is indicated in patients with positive non invasive tests or if a high index of suspicion is present in a patient with normal non invasive testing (30). In PAES arteriography is often entirely normal with the ankle in a neutral position and the knee extended. Therefore, it is important to repeat the studies bilaterally with the ankle in positions of provocation because extrinsic arterial obstruction can often be demonstrated with ankle plantarflexion. Careful assessment is required for both the symptomatic and the contralateral limb as the condition can be present bilaterally in up to 25% of cases (35).

The vessels both proximal and distal to the knee are usually normal, thus helping to distinguish the condition from early onset atherosclerosis. In a review article by Murray *et al.* (6), 66% of cases had a localized occlusion of the popliteal artery, medial deviation of the artery was present in 29%, popliteal

stenosis alone in 1%, popliteal aneurysm in 4% and poststenotic dilatation in a further 8%. Stenosis of the popliteal artery is enhanced with hyperextension of the knee and either passive dorsiflexion of the ankle or active plantarflexion of the ankle (35). This group also found that in bilateral cases, the same anatomic abnormality was present on both sides in 87% of cases.

Other imaging techniques such as Computerized Tomography (CT) (13), Magnetic Resonance Imaging (MRI) (38) and dynamic Magnetic Resonance Angiography (dMRA) (40) have more recently been recognized as playing a potentially important role in the diagnosis of PAES. MRI with its better definition of soft tissue structures will likely become more popular as an investigative tool in the future. These advanced procedures allow for an accurate morphologic diagnosis and can therefore serve as a very useful supporting examination in PAES. Additionally, providing an accurate morphologic diagnosis of PAES can assist in the choice of a surgical approach (6).

Differential Diagnosis

The differential diagnosis of PAES can be broken down into: 1) Vascular 2) Local Musculoskeletal and 3) Central Neurologic etiologies:

<u>Vascular</u>	<u>Local Musculoskeletal</u>	<u>Central Neurologic</u>
Atherosclerosis	Gastrocnemius/Soleus Strain	Spinal Stenosis
Buerger's Disease	Medial Tibial Stress Syndrome	
Trauma	Periostitis	
Popliteal Aneurysm	Compartment Syndrome	
Adventitial Cystic Disease	Stress Fractures	
Extrinsic Compression	Tibialis Posterior Tendinitis	
Cardiac Embolism	Muscular Anomalies	
Deep Venous Thrombosis		
Venous Entrapment		

Treatment

The treatment of PAES is surgical and depends on symptoms, underlying abnormal anatomy and the degree of damage to the popliteal artery. As the natural history of the condition is believed to be one of progression to arterial injury and embolization, intervention is usually recommended. The principles of treatment are to release the entrapment and to restore normal arterial flow.

The surgical procedure most commonly employed is a simple myotomy and release of offending fibrous bands (13,16). This procedure is undertaken when there is no evidence of arterial damage as evaluated through preoperative investigation, clinical features and examination of the artery at surgery. With evidence of arterial damage, the surgical procedure becomes more complicated. When arterial stenosis is present endarterectomy and vein patch angioplasty have been performed (37). Complete occlusion of the popliteal artery can occur and is often repaired with a saphenous vein bypass graft (15). In the event of a poststenotic aneurysm in PAES, resection of the aneurysm with a venous bypass graft has been described in the literature (36).

Surgical repair of an asymptomatic limb with PAES has been increasingly advocated to prevent the arterial injury that is believed to be the outcome associated with the natural progression of the syndrome (16).

Prognosis

There are few long-term follow-up studies in the literature to date.

L. di Marzo *et al.* in 1991 (7) described their 10 year experience with the surgical treatment of PAES. They reported on 31 cases in 23 patients. Of these, 19 were males (83%) and 4 were females. Symptoms were described as: moderate (calf cramping after intense physical training, paresthesiae etc.) in 14 limbs, intermittent claudication in 16 and necrosis (of a big toe) in one. Preoperative arteriography showed arterial occlusion in 8 limbs, stenosis in 8 and aneurysms in 2. Surgical treatment consisted of division of

the aberrant musculotendinous tissue in 18 cases. In 12 cases a vascular reconstruction was also required, while 1 case was explored without a specific procedure being performed. Patients in whom the muscle was divided without additional arterial surgery had the best long term patency rate, calculated as 94.4% (mean follow-up 46.0 months, min. 2, max 120 months). However, their definition of patency rate was not defined and it is not clear whether they used clinical and/or vascular studies to assess this. One case failed after 13 months with an occluded popliteal artery. This individual was left with only mild claudication because of good collateral flow. The authors stated that in retrospect that they should have done a reconstructive procedure instead of a musculotendinous release for the first operation.

The long-term patency of the 12 cases submitted to vascular reconstruction was 58% (mean follow-up 43.5 months, min. 1, max. 100 months). Five grafts failed (41.7%), 1 and 2 months after surgery and had further reconstructive procedures. Three cases failed after 1, 6 and 20 months without the need for new vascular reconstructions. The outcome of these individuals was not described in the paper.

From this article it appears that individuals who are treated with a simple myotomy at an early stage of their disease had a lower rate of complications (as judged by graft failure) than those individuals who underwent reconstructive procedures. Intuitively this makes sense that individuals with normal arteries have a better outcome than those with damaged arteries.

Schurmann *et al.* in 1990 (39) reported on a 12 year experience with 13 cases in 11 patients (8 males and 3 females). The average age was 38.3 years with a range from 15 to 61 years. The presenting features were listed as: claudication in 9 limbs, rest pain and toe necrosis in 1 limb and no symptoms in 1 limb. In 2 limbs the symptoms were not described. The operations performed in this series were more extensive than in the series reviewed above. Ten of the 13 limbs had venous patches or venous interposition procedures. Thromboendarterectomies were undertaken in 5 limbs and bypass procedures were done in 2 patients.

Of the 13 limbs operated on for PAES, 8 were labelled as having an excellent result. On histological examination 3 limbs had evidence of atherosclerosis, 2 limbs had evidence of atherosclerosis and

thrombosis, 1 had atherosclerosis and an aneurysm and 1 had atherosclerosis, thrombosis and an aneurysm. Additionally, 1 limb did not have histological results. From the study it appears that any case with an uncomplicated postoperative course was labelled as an excellent result by the study authors.

Three limbs required bypass procedures in the postoperative period. Of these, one limb was treated with a primary bypass as the definitive surgery and 1 year post operation this patient underwent a femoro-crural bypass to treat an aneurysm. The other two both had myotomies, thromboendarterectomies and venous procedures as their definitive operations. Their bypass procedures were undertaken at 6.5 and 9 years post operation.

One patient thrombosed his venous graft on the fourth postoperative day and developed further thrombosis and an aneurysm after 16 months. The last patient was left with foot claudication while running.

From this series and the one of di Marzo it is evident that complications from PAES surgery can occur both early and late in the postoperative period. Additionally, individuals with reconstructive procedures seem to have more complications than individuals with simpler operations. This strengthens the premise that individuals with PAES who have no evidence of arterial damage are in a markedly different prognostic group with respect to postoperative complications than those with arterial damage. Again, the lack information regarding what constitutes an excellent result precludes its usefulness in defining prognosis for individuals undergoing PAES surgery. Does the absence of postoperative complications signify an excellent result?

Collins *et al.* (16) are the third group of researchers that have published data in the English language on the postoperative course of their PAES patients. Collins series was collected over an 11 year period from a military population. Twelve patients (10 male and 2 female) with an average age of 27 years (range from 19 to 53 years) comprised the series. All the patients had a chief complaint of calf pain, and two also complained of foot pain with ambulation. Arteriograms were obtained in all 12 patients. Sixteen limbs had deviation of the popliteal artery's course or extrinsic compression of the artery with maneuvers or both. Four limbs had occluded vessels. Twenty limbs in 12 patients were shown to be abnormal and two thirds

of these patients had bilateral popliteal artery entrapment. At surgery 4 arterial reconstructions were performed; two popliteal artery thromboendarterectomies and two saphenous vein interposition grafts. One patient refused surgery and could not be classified. After surgery, all patients were evaluated with exercise treadmill tests at one month, with 8 of the 12 patients having complete relief of their symptoms and no decrease in their ABI's.

Of the 11 patients that underwent surgery, 7 were classified as having excellent results. As with the studies above, what constitutes an excellent result was not defined. The remaining 4 patients were described as having good results. Two of these individuals had normal treadmill results and improved leg symptoms but they were unable to return to active military duty. The reason why they were not able to return to active duty was not given. The other two individuals classified as having good results developed occlusions of their arterial reconstructions and developed unspecified mild symptoms.

This study had a short period of follow-up (1 month) for individuals without complications. We know from the above studies that complications can occur in the late postoperative period. Additionally, the classification of individuals who developed arterial occlusions as having "good results" is debatable. Furthermore, this series as with the studies already reviewed, poorly defined their results classifications.

In summary, there are very few follow-up studies of individuals who have undergone PAES surgery. Those that have been done suffer from significant methodological problems. Thus, it remains difficult to define the prognosis for individuals with PAES surgery. What is evident from reviewing the literature is that to date the results of PAES surgery have been defined on the presence or absence of complications. PAES has been found to occur most commonly in young athletes (6) who seek medical attention because of exercise-induced lower limb symptoms that limit or interfere with their ability to exercise. Presumably, the patients would judge the success of this operation not only on the arterial patency rate, but also on the ability of the procedure to allow activity without lower limb symptoms. This aspect of PAES surgery has been totally ignored in the literature.

APPENDIX II

Questionnaire for Popliteal Artery Entrapment Syndrome Surgery

Date

Code # ____

Occupation

Education Level

Time Periods:

1) **PRIOR TO SYMPTOMS**--- The period of time before the leg pain with exercise began

2) **PEAK SYMPTOMS**--- The period of time when the leg pain from exercising was at its peak

(to help you to remember, you were seen at The Sports Medicine Centre at UBC for the first time on _____, your first appointment with your surgeon was on _____ and your surgery was on_____,.)

Please give the **month** and **year** when your leg pain from exercising was at its peak_____

3) **PRESENT TIME**--- The period of time encompassing the last 6 months

What was the length of time (weeks) from your surgery to return to work or school (at least part-time) ?

What was the length of time (weeks) from your surgery to return to the Activities/Sports that were most affected by the leg pain ?

1. Activity Level

1) The **Participation** scales look at whether there have been any changes in your performance for the time periods listed below:

Time Periods:

1) **BEFORE SYMPTOMS**

2) **PEAK SYMPTOMS**

3) **PRESENT TIME**

Please rate your overall activity level during the period of time just before your leg symptoms while exercising began

The Least Active That
You Have Ever Been

The Most Active That
You Have Ever Been

Please rate your overall activity level during the period of time when your leg symptoms while exercising were at their peak

The Least Active That
You Have Ever Been

The Most Active That
You Have Ever Been

Please rate your overall activity level in the past 6 months (at the present time)

- 2) The **Reasons For Change In Participation** table looks at why your activity level may have changed over the time periods in the last table.

New Time Periods:

1) **BEFORE SYMPTOMS TO PEAK SYMPTOMS**

2) **PEAK SYMPTOMS TO PRESENT TIME**

3) **BEFORE SYMPTOMS TO PRESENT TIME**

Reasons for Change:

- a) Change in activity level due to an improvement or worsening of leg pain while exercising (**LPE**)

(SCALE OF 1 TO 3, 1=NOT IMPORTANT....3=VERY IMPORTANT)

- b) Change in activity level due to **OTHER** reasons

(SCALE OF 1 TO 3, 1=NOT IMPORTANT....3=VERY IMPORTANT)

If there has (had) been no change in your activity level for a particular activity
please mark an **X** in each appropriate column

Please list "**OTHER**" factors_____

Reasons For Changes In Participation

	<u>BEFORE TO PEAK</u>		<u>PEAK TO PRESENT</u>		<u>BEFORE TO PRESENT</u>	
	<u>LPE</u>	<u>OTHER</u>	<u>LPE</u>	<u>OTHER</u>	<u>LPE</u>	<u>OTHER</u>
Aerobics						
Basketball						
Cycling						
Dancing						
Hiking						
Hockey						
Running						
Soccer						
Swimming						
Tennis						
Triathlon						
Volleyball						
Walking						
Other (LIST)						

2. Performance

- 1) The **Performance** scales look at whether there have been any changes in your performance for the time periods listed below:

Time Periods:

- 1) **BEFORE SYMPTOMS**
- 2) **PEAK SYMPTOMS**
- 3) **PRESENT TIME**

Please rate your overall activity performance during the period of time before your leg symptoms while exercising began

The Worst Performance
That You Have Ever Had

The Best Performance
That You Have Ever Had

Please rate your overall activity performance during the period of time when your leg symptoms while exercising were at their peak

The Worst Performance
That You Have Ever Had

The Best Performance
That You Have Ever Had

Please rate your overall activity performance during the past 6 months (at the present time)

The Worst Performance
That You Have Ever Had

The Best Performance
That You Have Ever Had

2) The **Reasons For Change In Performance** table looks at why your performance level may have changed over the time periods in the last table:

New Time Periods:

1) **BEFORE SYMPTOMS TO PEAK SYMPTOMS**

2) **PEAK SYMPTOMS TO PRESENT TIME**

3) **BEFORE SYMPTOMS TO PRESENT TIME**

Reasons for Change:

- a) Change in performance level due to limitation from **leg pain while exercising**
(**LPE**)

(SCALE OF 1 TO 3, 1=NOT IMPORTANT....3=VERY IMPORTANT)

- b) Change in performance level due to **OTHER** reasons

(SCALE OF 1 TO 3, 1=NOT IMPORTANT....3=VERY IMPORTANT)

If there has (had) been no change in your performance level for a particular activity please mark an **X** in each column

Please list "**OTHER**" factors_____

Reasons For Change In Performance

	<u>BEFORE TO PEAK</u>		<u>PEAK TO PRESENT</u>		<u>BEFORE TO PRESENT</u>	
	<u>LPE</u>	<u>OTHER</u>	<u>LPE</u>	<u>OTHER</u>	<u>LPE</u>	<u>OTHER</u>
Aerobics						
Basketball						
Cycling						
Dancing						
Hiking						
Hockey						
Running						
Soccer						
Swimming						
Tennis						
Triathlon						
Volleyball						
Walking						
Other (LIST)						

3. Lower Limb Problems With Exercise

In your own words describe what you felt in your leg(s) and/or foot (feet) **at the time of peak pain while exercising**

In your own words describe what you have been feeling in your leg(s) and foot (feet) while exercising **within the past 6 months (at the present time)?**

- 1) For the scales **Intensity of Lower Limb Symptoms**, please rate the level of intensity of your leg(s) and/or foot (feet) symptoms listed above, for the following time periods:

Time Periods:

1) **Peak Symptoms**

2) **Present Time**

Please rate the intensity of your leg symptoms while exercising when they were at their peak

Please rate the intensity of your leg symptoms while exercising in the last 6 months (at the present time)

2) For the scales **Level Of Activity For Symptom Onset** please describe the level of activity at which your symptoms listed above are noticeable for each of the time periods below:

Time Periods:

1) **Peak Symptoms**

2) **Present Time**

Please rate your level of activity level that brought out leg symptoms when the symptoms were at their peak

Please rate your level of activity level that will bring out leg symptoms within the past 6 months (at the present time)

Please rate the ability of PAES surgery to return you to your level of activity participation that you had before developing symptoms

Please rate the ability of PAES surgery to return you to your level of activity performance that you had before developing symptoms

Please rate the ability of PAES surgery to relieve leg symptoms while exercising

Please rate your overall satisfaction with the PAES surgery

poor

fair

good

excellent

HISTORY AND PHYSICAL EXAMINATION

Co-Morbid Medical Problems (eg. Injuries, Arthritis, Respiratory, CV , Psy)

Risk Factors For Atherosclerosis

Current Medications

Risks For Exercise On The Treadmill

Treadmill Test

<u>Time</u>	<u>Treadmill Speed</u>	<u>Grade</u>	<u>Symptoms</u>
0-1	3	0	
1-2	4	0	
2-3	5	0	
3-4	6	0	
4-5	7	0	
5-6	8	0	
6-7	9	0	
7-8	10	0	
8-9	10	10	
9-10	11	10	
10-11	12	10	
11-12	13	10	
12-13	14	10	
13-14	15	10	
14-15	16	10	