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Low-bandwidth, Internet-based videoconferencing for physical rehabilitation consultations

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Summary

Low-bandwidth, Internet-based videoconferencing was used to provide physical rehabilitation consultation services for eight community hospitals. Videoconferencing and file transmission used a PC and modem. A separate telephone line was used for voice. Over 21 months, 47 physical rehabilitation consultations were completed for communication disorders, foot care, gait problems, orthotics, prosthetics, arm weakness and wheelchair prescription. Consultations were approximately 40 min long. Clinician questionnaires were completed by 47 individuals. While more than 80% of the questionnaire responses supported the telemedicine approach, remote clinicians rated their satisfaction higher than did the specialists. Client questionnaires were completed by 24 individuals (a response rate of 51%). All clients were comfortable with and had confidence in the teleconsultations.

Introduction

Telemedicine is undergoing a phase of expansion. However, the rehabilitation field has been relatively slow to integrate telecommunication tools into clinical practice. This is surprising since telemedicine has many benefits for an outreach physical rehabilitation service. These include:

(1) *Decreased travel between rural communities and specialized urban health centres*. This saves time for clients and clinicians, and reduces cost. Moreover, in Canada, travel during winter is often difficult or unsafe.
(2) *Better clinical support in local communities*. Some people with disabilities, such as people with head injuries, require continuing assistance from a team of health-care professionals. However, the goal of the rehabilitation team and the family is normally social integration into the community.
(3) *Improved access to specialized services*. Some people who require rehabilitation or long-term care services should not be moved.
(4) *Delivery of local health-care in rural communities*. Many people in rural communities do not feel comfortable in large urban centres.
(5) *Indirect educational benefits for remote clinicians who participate in teleconsultations*.
(6) *Reduced feelings of isolation for rural clinicians*.
(7) *Improved service stability in regions with high staff turnover*. This is especially true of remote regions.
(8) *Multimedia communication*. Video pictures, rather than voice alone, are required when dealing with complex clinical situations and rehabilitation equipment.

Telemedicine has been described as a combination of technologies used to support a wide variety of applications[1]. Successful telehealth trials have been completed with home response systems[2], on-line communities[3], cardiology[4], diabetic care[5], dermatology[6], neurosurgery[7], pathology[8], psychology[9], psychiatry[10], radiology[11], oncology[12], ophthalmology[13], orthotics[14,15], physical rehabilitation[16], surgery[17,18] and space exploration[19]. However, few structured research projects for telerehabilitation have been reported in the peer-reviewed literature.

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Kim[20], Scheck[21] and Temkin *et al.*[22] have described a telerehabilitation programme established between the Shepherd Center (Atlanta, GA), the Sister Kenny Institute at the Catholic University (Washington, DC) and the National Rehabilitation Hospital (Washington, DC). This programme aimed to bridge the gap between a client's home and a central rehabilitation centre. The components included a data communications unit that plugged into a television set, a telephone line and a video-camera. The system cost approximately US$10,500 (US$1 is EU1.05). The communication device transmitted simultaneous audio and video-pictures over the ordinary telephone network at 33 kbit/s. A home-care nurse or technician could adjust the equipment according to the rehabilitation specialist's needs. Video-pictures typically had up to a 10 s delay and could be blurred. Possible uses of this system included the management of pressure sores, urinary tract infections, respiratory problems, chronic pain, depression and spasticity.

A similar system was implemented by the University of New Brunswick and the Stan Cassidy Centre for Rehabilitation (SCCR). It was used to link the SCCR to clients' homes[23]. The project team developed a 'user friendly interface to the Internet using a computer, video camera and related software'. The results of this project have yet to be published.

Malagodi *et al.*[24] compared videoconferencing using ordinary telephone lines with videoconferencing using ISDN lines. Over six months, an occupational therapist completed eight seating and wheelchair mobility evaluations. Four clients were evaluated by video-conferencing using the telephone line and four clients were evaluated using an ISDN line (128 kbit/s). The results of these eight evaluations were compared with previously completed face-to-face evaluations.

The maximum connection speed over the telephone line was 16.8 kbit/s. This low speed was due to poor-quality telephone lines. Even with the poor line conditions, the primary condition and major problem were correctly identified in all cases. The general recommendations for each case were similar to those made after a face-to-face consultation. While the results were similar, the evaluations conducted over telephone lines took longer to complete than the face-to-face encounters. The slower (telephone) data communications rate led to longer still-picture transfer times and smaller and jerkier video images than was achieved with the ISDN connection. Neither video-conferencing system could detect a 4–7 Hz tremor in one subject's hands.

The authors made various suggestions concerning the most appropriate methods for conducting distance evaluations:

(1) extra effort should be made to establish rapport between the specialist, the remote clinician and the client;
(2) the specialist should have control of the evaluation but must defer control to the remote clinician when safety becomes a concern;
(3) complicated evaluations should be completed between the specialist and a registered therapist (as opposed to a family member or a health-care aide);
(4) clothing colour can hamper a videoconferencing evaluation if it is similar to the colour of a client's wheelchair.

All subjects felt comfortable about being evaluated on-line and felt that the results were as accurate as a conventional evaluation. The subjects were satisfied with the evaluation process. Overall, the subjects and clinicians considered telerehabilitation to be ready for routine clinical use.

Lemaire and Jeffreys[14] carried out a controlled study to evaluate an Internet-based telemedicine system for rehabilitation assessments. Computers in an urban centre and two rural communities were linked using the Internet by a modem connection at 28.8 kbit/s. The conferencing system provided live video-pictures, a shared whiteboard and file transfer services. A second telephone line was used for audio. Motion analyses were performed by storing 20 frame/s video-clips on the hard disk and then transmitting the video-file to a specialist. Database records were sent between sites by file transfer.

Twenty-two people who required ankle–foot orthotics were evaluated using a desktop video-conferencing system. Each subject was also evaluated in person. Assessment results were similar between the two groups in over 88% of cases. Most discrepancies were in the prescription, history, goals and complications sections of the assessment. This was understandable, since many clients took part in the study but did not have new medical problems and did not have a prescription. Discrepancies with physical measures related to different backgrounds between the orthotist (at the urban centre) and the physiotherapist or occupational therapist (at the remote sites). Some discrepancies in the gait analyses could have been caused by insufficient clarity in the video-clips, for example for the detection of fine motions such as inversion/eversion. Satisfaction with the telemedicine approach was high for clients, remote clinicians and rehabilitation specialists.

Although these studies have supported the use of telemedicine for physical rehabilitation consultations, it does not seem to have been employed in rural community facilities. We have used Internet-based videoconferencing in a physical rehabilitation

outreach programme and the present paper describes the evaluation results.

Methods

Eight community hospitals and one specialized physical rehabilitation hospital were involved in the project. The community facilities were located in the eastern and north-eastern regions of Ontario — Arnprior and District Memorial Hospital, Cornwall General Hospital, Hawkesbury General Hospital, Englehart and District Hospital, Kirkland and District Hospital, Pembroke General Hospital, St Francis Memorial Hospital (Barry's Bay) and Temiskaming Hospital (New Liskeard). All specialized physical rehabilitation services were provided by the Terry Fox Mobile Clinic, a multidisciplinary outreach service of the Rehabilitation Centre in Ottawa.

The project protocol was approved by the Rehabilitation Centre's research and ethics review committee and representatives from each partner facility. All clients involved in the study were informed about the protocol and completed a consent form before participating in an on-line session.

Equipment

Communication software and video-capture cards were provided to each site by the Rehabilitation Centre. However, lack of funding prevented two sites from purchasing equipment in the first year. Funding was subsequently obtained to equip all sites with the same videoconferencing systems (see Table 1). A conferencing workstation cost approximately C$4000 (C$1 is US$0.66, EU0.7).

Each videoconferencing system was connected to the Internet via a local Internet service provider. Each hospital was responsible for the costs and maintenance of their dial-up Internet access point. The costs of dial-up Internet access and staff time were affordable by the rural communities.

Table 1 The components of the videoconferencing system

Item	Description
Computer	Pentium III 450, 12 GB hard drive, 128 MB RAM, 32× CD-ROM, 56 kbit/s modem, 43 cm Trinitron monitor
Video-capture card	3COM Bigpicture Video
Desktop conferencing software	Microsoft NetMeeting
Video-capture and editing software	PictureWorks Live
Speaker-phone	A good-quality speaker-phone
Camcorder and tripod	Hi8 Palmcorder

Two telephone lines, one for the speaker-phone and one for the modem, were used to ensure that audio and data communication could not affect each other. Previous tests on videoconferencing systems that used 33 kbit/s Internet-based communication have shown that audio quality is unreliable when large video or data files are being transferred over the same connection[14].

The core communication software was NetMeeting (Microsoft), which included most of the tools necessary to complete a physical rehabilitation consultation, such as live video and audio conferencing, shared whiteboard, file transfer and application sharing. Specially written software was used to assist with gait analysis (this can be downloaded from http// www.rohcg.on.ca/cag/mat).

All users received one training session at their site. Depending on the users' computer experience, these training sessions covered everything from turning on the computer to running NetMeeting. The session was not considered complete until the user could connect to the Internet, start NetMeeting and call another user. Subsequent training sessions were completed using NetMeeting itself. Users required between one and four follow-up training sessions before completing a client consultation.

Evaluation

Satisfaction questionnaires were completed by the client (see Appendix), remote clinician and rehabilitation specialist (Table 2) after each on-line session. Clinicians rated ease of use, ability to understand the remote person, ease of assessment, confidence in the assessment results and overall satisfaction on five-point scales. The remote clinician and rehabilitation specialist recorded their time on-line and time off-line for each consultation.

Client questionnaires were used to rate the duration of the consultation, feeling while participating in the telemedicine session and overall satisfaction, again on five-point scales. Confidence in the assessment was simply rated 'yes' or 'no'. Other questions recorded what the client liked and disliked about the session, how the session could be improved and any additional comments.

Consultation times were compared between sites using paired *t*-tests. Clinician ratings were compared between sites using Mann–Whitney *U*-tests. All other data were analysed using descriptive statistics. In addition to the formal evaluation, a debriefing session was held with representatives from all eight community facilities.

Table 2 Summary of the clinician questions and response options

	Response options
Computer time	The number of minutes from initiating the computer communication session to terminating the communication session
Off-line time	The number of minutes spent performing tasks not directly related to the computer communication session. This includes looking up information, breaks, etc.
Computer malfunctions	Indicate if a computer problem occurs during the communication session. This includes losing the communication line, program crashing, inability to access a program feature because of a hardware or software problem, etc. Please indicate yes or no and describe the problem
Ease of use (1–5 rating)	The ease of accomplishing the tasks related to this communication session over the computer system. Please enter 1 to 5 where: 1 = unacceptable; 2 = poor; 3 = acceptable; 4 = good; 5 = excellent
Ability to understand the remote person	The ease of communication with the other person over the computer system (i.e. understand what they want, understand their responses, etc.). Please enter 1 to 5 where: 1 = cannot understand; 2 = understand a little; 3 = understand most things; 4 = understand almost everything; 5 = understand everything
Ease of assessment	The ease of assessing the client over the computer system. Please enter 1 to 5 where: 1 = much worse than a manual assessment; 2 = worse than a manual assessment; 3 = as easy as a manual assessment; 4 = better than a manual assessment; 5 = much better than a manual assessment
Confidence in assessment results	The level at which you are sure that the correct assessment was made. Please enter 1 to 5 where: 1 = much less confidence than in a manual assessment; 2 = less confidence than in a manual assessment; 3 = as much confidence as in a manual assessment; 4 = more confidence than in a manual assessment; 5 = much more confidence than in a manual assessment
Satisfaction with assessment	Clinician satisfaction with the client assessment. Please enter 1 to 5 where: 1 = unsatisfied (must redo assessment); 2 = poor; 3 = average; 4 = good; 5 = excellent

Results

All eight community sites and the specialized rehabilitation site included remote clinical consultations and continuing education sessions as part of their everyday practice. Between June 1998 and February 2000 a total of 47 consultations took place (for 27 male clients and 20 female). These consultations covered a wide variety of clinical situations, including communication disorders, foot care, gait problems, orthotics, prosthetics, arm weakness/joint degradation and wheelchair prescription. To address these issues, specialists were drawn from the fields of chiropody/podiatry, medicine, nursing, occupational therapy, orthotics, physiotherapy, prosthetics, social work and speech pathology. The majority of teleconsultations involved exercise prescription, assistive devices, equipment adaptation and modification of the client's environment. Approximately half the consultations were primarily handled by a physiotherapist, 20% by prosthetics/orthotics, 20% by speech pathology, 8% by nursing and 2% by occupational therapy staff. Twelve specialists and 10 community clinicians participated in on-line consultations. Since Canadian physical medicine specialists are not remunerated for teleconsultations, medical consultations were usually completed during outreach visits by the rehabilitation team.

No significant differences ($P<0.05$) were found between consultation times at the central and remote sites (Table 3). The average consultation time of 42 min was considered acceptable by the rural clinicians and rehabilitation specialists. The majority of off-line time was spent capturing, sending and analysing digital video-clips. Since the video-capture rate was approximately 1 frame/s and the image was small, video-clips were stored at a resolution of 320×240

Table 3 Time spent during consultations (min) (n = 47)

	Rehabilitation site		Remote site	
	Conferencing time	Off-line time	Conferencing time	Off-line time
Mean (SD)	42.0 (20.2)	25.7 (34.6)	41.3 (19.6)	29.7 (26.4)
Maximum	90	210	90	90
Minimum	0	0	0	0

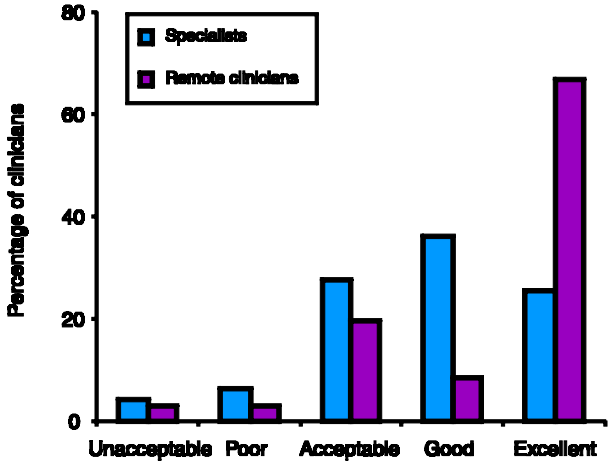

Fig 1 Clinician questionnaire results ($n = 47$) for ease of use.

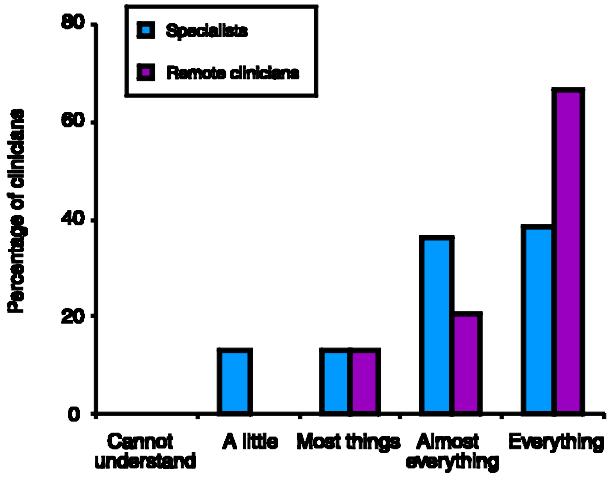

Fig 2 Clinician questionnaire results ($n = 47$) for ability to understand.

pixels and 15 bits, at 30 frames/s, before being sent to the specialist for motion analysis. The 15-bit video-pictures provided appropriate colour quality while minimizing the file size of the video-clip.

System failures occurred in nine cases. Three occurred at the start of the project and two others occurred on the same day, in association with system upgrading.

Clinician questionnaires were completed by 47 individuals. The clinicians' views about the consultation process are shown in Figs 1–5. Remote clinicians gave significantly higher ratings than the rehabilitation specialists for ease of use, ease of assessment and overall satisfaction ($P<0.05$). While the results from the remote clinicians and specialists were not significantly different for ability to understand the remote person and confidence in the

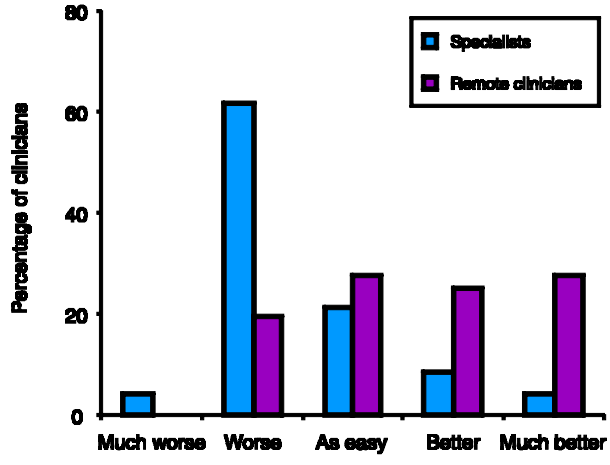

Fig 3 Clinician questionnaire results ($n = 47$) for ease of assessment.

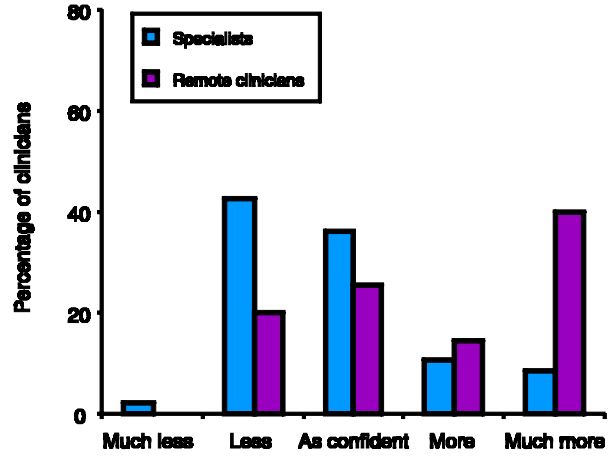

Fig 4 Clinician questionnaire results ($n = 47$) for confidence in assessment.

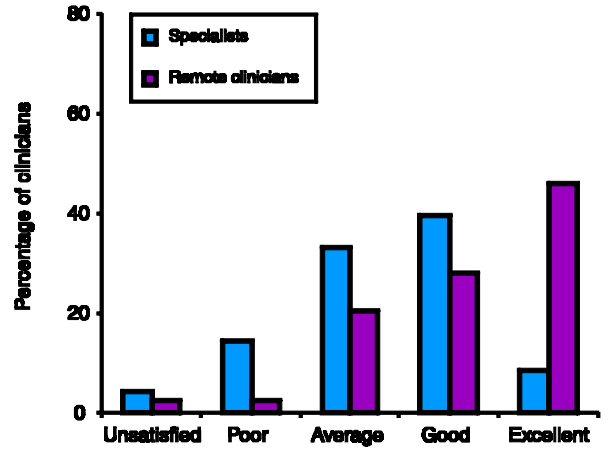

Fig 5 Clinician questionnaire results ($n = 47$) for overall satisfaction.

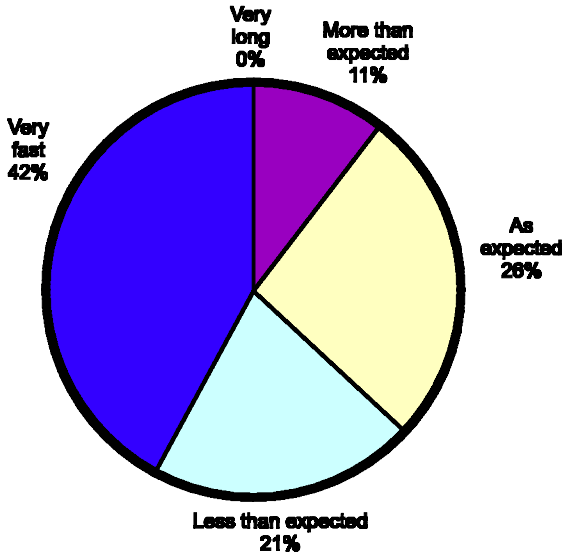

Fig 6 Client questionnaire results (n = 24) for session length.

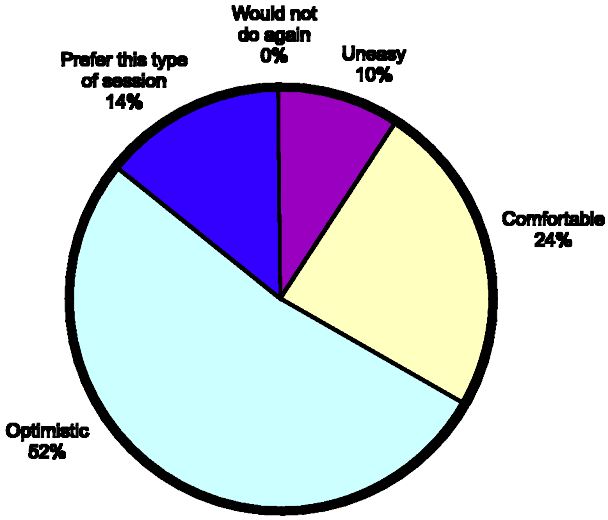

Fig 7 Client questionnaire results (n = 24) for comparison between teleconsulting and conventional methods.

assessment, the trend was for the ratings of the remote clinicians to be higher. The ratings for ease of assessment and confidence in assessment were in relation to how the consultation would have progressed in person, that is without telemedicine. Over 80% of the responses related to ease of use, understanding and overall satisfaction supported the use of teleconsulting. Sixty-five per cent of the rehabilitation specialists' questionnaires indicated that teleconsultations were not as easy to complete as in-person consultations. Almost 80% of remote clinicians considered teleconsultations to be as easy, or easier, than in-person sessions. Fifty-five per cent of specialists and 80% of remote clinicians were as confident in the outcome as they would have been after an in-person consultation.

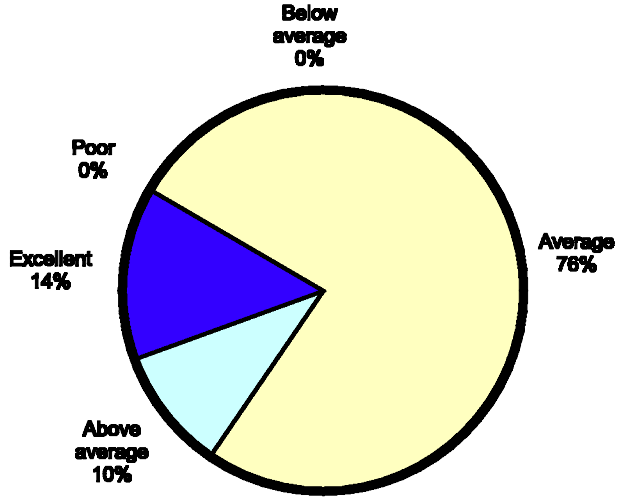

Fig 8 Client questionnaire results (n = 24) for overall feelings about the teleconsultation.

Client questionnaires were completed by 24 individuals (18 females and 6 males), a response rate of 51%. All clients were comfortable with the on-line session and confident about the results. Almost 90% of the clients considered the consultation time to be either appropriate or faster than expected. Ninety per cent of the clients felt as comfortable or more comfortable with the teleconsultation as with a conventional appointment. The client questionnaire responses are summarized in Figs 6–8.

Discussion

Both urban and rural clinicians were supportive of the telemedicine process for remote consultations. However, remote clinicians gave significantly higher satisfaction ratings than rehabilitation specialists. It was not surprising that the remote clinicians gave higher ratings for ease of use, ease of assessment and satisfaction because these professionals had access to specialized expertise that was not otherwise available in their community. In contrast, the rehabilitation specialists had the task of completing a consultation without seeing the client face to face and teleconsultations require a clinician to work in an unfamiliar way.

Most of the complaints about ability to understand were related to poor audio quality from the speaker-phones, rather than poor connections caused by problems with the telephone network. Good-quality audio is essential for remote consultations and good-quality speaker-phones should be used for

teleconsulting. The only unsatisfactory sessions occurred when technical or Internet connection problems required the clinicians to reschedule an appointment.

Consultation time results confirmed that teleconsultations do not save time for health-care specialists. The combination of on-line and off-line time was longer than a typical rehabilitation consultation (an informal survey of clinician appointment schedules was used as the comparator). While faster data lines may speed up the consultation process itself, the main reason for the increased duration was the added complexity of an on-line consultation. Although the consultation time was longer than a conventional appointment, a duration of 40 min was considered acceptable since the only alternative was to travel to the community or send the client to the specialized rehabilitation centre.

Videoconferencing systems based on personal computers are best used for small groups (fewer than eight people). Larger groups may not be able to see the screen or communicate well over the speaker-phone. Using a telemedicine system helps to reduce the feelings of isolation that are common in rural health-care settings by providing access to specialized expertise and continuing education. In addition to accessing specialist services, such systems can be used to share information and videoconference with neighbouring communities. Since many issues are site specific, the clinical, administrative and environmental factors for each site should be considered when providing a telerehabilitation service.

The present study supports the use of low-bandwidth, Internet-based videoconferencing for many remote physical rehabilitation consultations. The results from this project should be applicable to many rehabilitation interventions that do not require realtime, full-speed video-pictures, as might be required, for example, for some speech pathology consultations.

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References

1 Kelly WT. Trends in telemedicine. Science Advisory Board — http://www.scienceboard.net (November 1998)
2 Fisk MJ. A comparison of personal response services in Canada and the UK. *Journal of Telemedicine and Telecare* 1995;**1**:145–56
3 Jackson JEF. A survey of a Canadian on-line substance abuse prevention initiative for adolescents and young adults. *Journal of Telemedicine and Telecare* 1995;**1**:217–23
4 Cheung ST, Davies RF, Smith K, Marsh R, Sherrard H, Keon WJ. The Ottawa Telehealth Project. *Telemedicine Journal* 1998;**4**:259–66
5 Bellazzi R, Riva A, Larizza C, Fiocchi S, Stefanelli M. A distributed system for diabetic patient management. *Computer Methods and Programs in Biomedicine* 1998;**56**:93–107
6 Lowitt MH, Kessler II, Kauffman CL, Hooper FJ, Siegel E, Burnett JW. Teledermatology and in-person examinations: a comparison of patient and physician perceptions and diagnostic agreement. *Archives of Dermatology* 1998;**134**:471–6
7 Pareras LG, Martin-Rogrigues JG. Neurosurgery and the Internet: a critical analysis and a review of available resources. *Neurosurgery* 1996;**39**:216–32
8 Ballis UJ. Telemedicine and pathology. *Clinics in Laboratory Medicine* 1997;**7**:245–61
9 Ball C, McLaren P. The tele-assessment of cognitive state: a review. *Journal of Telemedicine and Telecare* 1997;**3**:126–31
10 Baer L, Elford DR, Cukor P. Telepsychiatry at forty: what have we learned? *Harvard Review of Psychiatry* 1997;**5**:7–17
11 Boland G. Telemedicine in practice. *Seminars in Nuclear Medicine* 1998;**28**:145–57
12 Allen A. Practising oncology via telemedicine. *Journal of Telemedicine and Telecare* 1997;**3**:63–70
13 Yogesan K, Constable IJ, Eikelboom RH, van Saarloos PP. Tele-ophthalmic screening using digital imaging devices. *Australian and New Zealand Journal of Ophthalmology* 1998;**26** (suppl. 1):9–11
14 Lemaire ED, Jeffreys Y. Low-bandwidth telemedicine for remote orthotic assessment. *Prosthetics and Orthotics International* 1998;**22**:155–67
15 Lemaire ED, Jeffreys Y, Morazain G, Greene G. A model for remote orthotic assessment using distance communication technology. *Saudi Journal of Disability and Rehabilitation* 1997;**3**:1–14
16 Greene G, Lemaire ED. An evolution in outreach service delivery through computer distance communication. In: Smith TS, ed. *Rural Rehabilitation: A Modern Perspective*. Amaudville: Bow River Publishing, 1999: 195–214
17 Macedonia C. Three-dimensional ultrasound and image-directed surgery: implications for operating room personnel. *Seminars in Perioperative Nursing* 1997;**6**:133–6
18 Satava RM. Virtual reality and telepresence for military medicine. *Computers in Biology and Medicine* 1995;**25**:229–36
19 Doarn CR, Nicogossian AE, Merrell RC. Applications of telemedicine in the United States Space Program. *Telemedicine Journal* 1998;**4**:19–30
20 Kim H. The long view: selling providers on telerehab. *Teamrehab Report*, April 1999: 15–19
21 Scheck A. Going the distance: developments in communications technology bring telemedicine to rehab. *Teamrehab Report*, November 1998: 30–40
22 Temkin AJ, Ulicny GR, Vesmarovich SH. TeleRehab: a perspective of the way technology is going to change the future of patient treatment. *Rehab Management*, February/March 1996: 28–30
23 Biden ED. Internet based interactive video. *Canadian Medical and Biological Society Newsletter* 1998;**33**:18
24 Malagodi M, Schmeler MR, Shapcott NG, Pelleschi T. The use of telemedicine in assistive technology service delivery: results of a pilot study. *Technology: Special Interest Section Quarterly* 1998;**8**:1–4

Appendix. Summary of the client questionnaire

(1) Rate the time to complete this session. (1, Very long; 2, more time than expected; 3, as expected; 4, less time than expected; 5, very fast.)
(2) How did you feel while participating in the on-line session? (1, Would not participate again; 2, uneasy; 3, comfortable; 4, optimistic; 5, prefer this type of session.)
(3) Please rate your satisfaction with this on-line session. (1, Poor; 2, below average; 3, average; 4, above average; 5, excellent.)
(4) Are you confident with the results from this session? (Yes/no)
(5) What did you like about this session?
(6) What did you dislike about this session?
(7) How could this session be improved?
(8) Please list any other comments.