

Prehospital trauma system in a low-income country: system maturation and adaptation during eight years

Short title:

Trauma system maturation, Northern Iraq

Torben Wisborg, MD, DEAA
torben.wisborg@helse-finnmark.no

Mudhafar K Murad, MD
tcfiraq@yahoo.com

Odd Edvardsen, RN
odd.edvardsen@unn.no

Hans Husum, MD, PhD
hhusum@c2i.net

Affiliation of authors:

From the Department of Anesthesiology and Intensive Care, Hammerfest Hospital, Hammerfest, Norway (T.W.); the Trauma Care Foundation Iraq, Sulemaniyah, Northern Iraq (M.K.M.); Tromsø Mine Victim Resource Center, University Hospital of Northern Norway, Tromsø, Norway (O.E., H.H., T.W.).

The study has been financially supported by Northern Norway Regional Health Authority, Finnmark Hospital Trust and the Norwegian Department of Foreign Affairs.

Corresponding author: T. Wisborg, MD, DEAA, Hammerfest Hospital; N-9613 Hammerfest, Norway. E-mail: torben.wisborg@helse-finnmark.no. Fax: +47-78421205, phone: +47-78421234/+47-41634853.

Preliminary results were presented at the 2nd International congress on health, medication, and crisis management in disaster. Tehran, Iran, November 2004.

INTRODUCTION

Almost 90% of deaths from injuries occur in low- and middle-income countries (1), where injuries from road traffic accidents, interpersonal violence, and war are among the leading causes of death (2). Within these countries, there is a skewed distribution of resources, with most physicians and medical facilities located in major cities (3). The rate of prehospital death is highest in the countries with the fewest resources (4).

Improved prehospital treatment has significantly reduced mortality in low- and middle-income countries with short transportation times (5). Training of lay prehospital care providers has been reported to be successful in Ghana (4), and results from Mexico indicate that improved survival is largely dependent on the teaching of simple life-saving skills (6). The effects of layperson training are barely documented, and there have been calls for research on this subject (1, 7, 8).

We have previously reported reduced mortality after establishing prehospital trauma care systems in Northern Iraq and Cambodia, primarily designed to care for victims of mines and penetrating injuries (9). In Northern Iraq, the program was intended to train a core group of paramedics who in turn would train first responders in their areas. Northern Iraq has undergone major economic and structural changes since the start of the program in 1996, and we have seen the trauma system there confronted with changing injury patterns, requiring concordant changes in the system. We hypothesize that these changes represent an adaptive shift from the initial focus on mine injuries to being a general prehospital resource for affected villages and that the program has matured to deliver better care with reduced on-site delay.

The aim of the present study is therefore to describe adaptation and maturation in this trauma program, using retention of program paramedics, distribution of patient diagnoses, delays

of treatment and transportation, change in physiological indicators during the prehospital phase, and mortality as outcome measures.

MATERIALS AND METHODS

Training of paramedics and first responders

We trained a group of 20 paramedics in the rural parts of Northern Iraq during the years 1996–1999. Trainees were selected by the local physician from mine-infested villages situated far from medical facilities, and all had extensive personal experience in handling mine victims. They were obliged to remain in their village after training and were chosen with help from respected people in each village. A local Kurdish physician (M.K.M.) was teaching in co-operation with two expatriate teachers (H.H., T.W.) and supervised the paramedics and their activities between the yearly training periods.

After 1999, the local physician arranged new training courses with the help of the most experienced paramedics from the first training course. The training was based on a teaching manual for low-income countries (10), and the content of the original training program has been described in detail previously (11). Through these continued training courses 68 paramedics were trained from 1999 to 2005. In total 88 paramedics were trained in the program.

Paramedics were instructed to train layperson first responders in their own and neighboring villages on basic life support for trauma victims. This training was performed as two-day courses targeting all members of the village societies, including women and children. Specially skilled and interested participants were trained for a further two to three days as advanced first responders. This training included signs and symptoms of bleeding, venous cannulation, and administration of intravenous fluids. If these advanced first responders had a medical

background, they were also trained in pain management with ketamine as analgesia for trauma victims. A network of medics and first responders to strengthen the “chain of survival” from the site of injury to the hospital was thus established.

During the study period, local regulations dictated that all patients with serious mine and penetrating injuries were transferred to one surgical hospital in Sulemaniyah, while all other patients were treated at other hospitals. Due to this fact, Injury Severity Scoring, in-hospital mortality assessment and calculations of time intervals from injury to hospital were available only for the group of victims with penetrating injuries admitted to this hospital.

Data collection and statistics

Each paramedic reports all patient treatment in an injury chart. The charts are in Kurdish and are submitted to the local physician (M.K.M.) supervising the program. The local physician collects data concerning hospital treatment and mortality in a corresponding hospital chart. Mine victims found dead at the site of injury are also recorded in injury charts, with as much detail as possible. The local physician (M.K.M.) checks for consistent reporting of all injuries by frequent visits to villages in the target area and by monthly meetings with all paramedics. For the time period from 1996 to 2003, all charts were translated to English and brought to Norway for data processing. They are now entered into a database located in Sulemaniyah, Northern Iraq.

Scoring of anatomical severity of injuries was done by the local physician (M.K.M.) using the Abbreviated Injury Scale 90, update 98 (12) using all available information, including hospital records, x-rays, and findings during surgery. Because of local tradition, autopsies were not performed. Detailed medical records were available for all patients transferred to the surgical hospital, and scoring was done for all cases of penetrating injury with sufficient information. The

other hospitals had varying systems for record keeping, and severity scoring was not attempted for blunt injuries and medical emergencies.

This study is based on prospective injury charts from January 1, 1997 through December 31, 2004. In addition, a retrospective collection of details concerning interventions by first responders was done in the spring of 2004. This was a convenience sample of patients in whom first responders had assisted paramedics during the year 2003. The study was approved by the Regional Ethical Committee for Western Norway (05/9370-190.05) and the local Health Authorities in Sulemaniyah, in addition to the Norwegian Data Inspectorate (05/01721-2).

Data were entered into an Excel spreadsheet. Continuous variables are presented as means with the corresponding 95% confidence intervals (95% CI). Differences between means are given as 95% CI with the corresponding p value. For comparison of frequencies, we used Chi-square tests, and for comparison of means in continuous data we used t-tests or ANOVA. Bonferroni post-hoc tests were applied to data analyzed by ANOVA. Receiver Operating Characteristic (ROC) curves were used to estimate test accuracy (13). Comparison of groups was two-tailed with statistical significance set at $p < 0.05$. All analyses were performed using SPSS 11.0.

Outcome measures

Retention of paramedics in the program is reported as of November 2005, 9.5 years after the first training course. The changing panorama of the trauma system is described by diagnosis grouping of the patients.

Time intervals from injury to first medical help (by first responder or paramedic) and from injury to last medical assessment were recorded in the injury charts and the hospital charts. For

patients not admitted to a hospital, the time of the last assessment by paramedics was used as the endpoint.

In all patients over age 16, the physiological impact of the injury was evaluated by a three-component system described previously (9, 14) and similar to the Revised Trauma Score, with a maximum score of 12 points for the unaffected patient. A Physiological Severity Score (PSS) was calculated by multiplying the different components with standard vectors, as used for the Revised Trauma Score ($0.9368 \times$ consciousness score, $0.7326 \times$ systolic blood pressure score, and $0.2908 \times$ respiratory rate score) (15). The first assessment was done by the paramedic at first contact with the patient, and the last assessment was done on admission at the receiving facility. The effect of prehospital treatment was calculated as the PSS score before treatment subtracted from the score at the last assessment. Positive differences thus indicate physiological improvement and negative differences indicate deterioration. The ability of the initial PSS to predict mortality was tested using ROC curves for penetrating and blunt injuries separately, as well as for the rest of the material (medical emergencies, burns, drowning, obstetrics, etc.). An area under the ROC curve of 0.8 represents a reasonably powerful model, while an area of 0.95 is considered to indicate a high level of accuracy (13,16).

Information about mortality until the time of hospital discharge was available for victims of mines and penetrating injuries (gunshots, grenades, fuses, unexploded explosive ordnance, and stab wounds). To monitor development in the original mine injury management system, the mortality in this group of victims is reported separately, similar to our previous report (9). All other patients were referred to a number of hospitals where a reliable system for follow up on mortality could not be established.

Adaptation was assessed using the ability to treat a changing diagnosis panorama with uncompromised treatment effect as an outcome measure, and maturation was assessed by evaluation of time intervals, physiological impact of prehospital treatment, and mortality.

RESULTS

Paramedics and first responders trained

Paramedics were trained in four consecutive groups: the first group was trained by the expatriate physicians (H.H., T.W.) in cooperation with the local physician (M.K.M.), and the three other groups by the local physician and experienced paramedics. Details of retention are given in Table 1. As of November 2005, 72% of the paramedics were still in the program.

The paramedics trained approximately 6,000 first responders in their neighboring villages. In addition, 350 advanced first responders were trained.

Patients treated

A total of 2,349 patients received treatment during the period. Of these, 919 were mine and penetrating injuries, and 1,430 were blunt injuries or other emergencies such as medical emergencies, burns, drowning, or scorpion stings. Blunt injuries and other emergencies were collectively treated as “non-penetrating injuries.” The mean age in the groups differed slightly: mean age in the group with penetrating injuries was 27.6 years; in the group with non-

penetrating injuries, it was 26.4 years. In the group with penetrating injuries, 94% were male; 61% were male in the group with non-penetrating injuries.

The distribution of patient injuries is given in Figure 1. The frequency of mine and penetrating injuries decreased from 91% in 1997 to 15% in 2004 ($p < 0.0005$). The material was divided into three time intervals according to the decreasing frequency of mine injuries: 1997–1998 with 76% mine and penetrating injuries, 1999–2002 with 49% mine and penetrating injuries, and 2003–2004 with 21% mine and penetrating injuries (Fig. 2).

Time intervals from injury to first medical assistance and hospital admission

The mean time from injury to first medical help (by first responder or paramedic) was 1.2 hours (95% CI 1.1–1.3) and decreased from 2.4 hours (95% CI 1.3–3.5) in 1997 to 0.6 hours (95% CI 0.6–0.7) in 2004 (Fig. 3). The reduction was thus 1.8 hours and highly significant (95% CI 0.7–2.9, $p = 0.002$).

The mean time from injury to hospital admission was 4.9 hours (95% CI 4.6–5.3) for 740 patients where hospital charts were available, and this interval decreased from 9.6 hours (95% CI 5.6–13.6) in 1997 to 2.8 hours (95% CI 2.5–3.2) in 2004. The mean reduction was 6.8 hours (95% CI 2.8–10.8, $p = 0.001$).

Effects of prehospital treatment

Information about change in PSS from the site of injury (PSS1) to last medical assessment (PSS2) was available for 1,678 of 1,734 (96.8%) patients over age 16. Of these, 64 were found dead at the site of injury and were not included in the analysis.

1. Indicators of system maturation

For all victims, there was a significant increase in treatment effect from 0.52 (95% CI 0.33–0.72) in 1997–1998 to 0.94 (95% CI 0.86–1.02) and 0.81 (95% CI 0.71–0.90) in 1999–2002 and 2003–2004 respectively, as illustrated in Figure 4. The increase in PSS between 1997–1998 and 1999–2002 was 0.42 (95% CI 0.22–0.62, $p < 0.0005$). There was no significant difference between 1999–2002 and 2003–2004.

2. Effect of severity and injury type

The treatment effect was then assessed for penetrating injuries, blunt injuries, and all other conditions separately. To assess treatment effect in relation to injury severity, we divided each injury category into thirds based on the numerical distribution of the PSS before treatment. The results are summarized in Table 2.

The ability of the PSS to predict mortality was tested with ROC curves. The area under the curve was 0.94 (95% CI 0.9–0.99) for penetrating injuries, 0.98 (95% CI 0.97–0.99) for blunt injuries, and 0.77 (95% CI 0.68–0.87) for the rest of the patients (e.g., medical emergencies, burns, drowning, scorpion stings).

An anatomical injury severity score (ISS) was available for 475 of the 619 victims over age 16 with penetrating injuries. Treatment effect was also assessed for victims of penetrating injuries stratified into ISS groups of slightly injured (ISS < 9), moderately injured (ISS 9-15) and severely injured (ISS > 15) (Table 2).

In all categories of injuries, we found a consistent significant improvement of physiological function after prehospital treatment in the severely and moderately injured groups, while the slightly injured showed little or no change. The finding was consistent also when the penetrating injuries were stratified based on ISS.

Agreement between the last PSS assessment done by paramedics and first PSS assessment done at the surgical hospital was calculated for 545 patients with penetrating injury and complete data for both assessments. ANOVA analysis demonstrated no difference between the scoring by paramedics and hospital staff (mean difference 0.02, 95% CI – 0.01 to 0.05). Linear regression analysis of the two scorings fitted well to the line of equality. In a Bland & Altman plot (Figure 5) less than 5% of observations were found outside the boundaries of agreement, and the agreement index was 0.91, indicating excellent agreement (17).

Mortality in the group with mine and penetrating injuries

The mortality among victims of mine and penetrating injuries decreased during the study period from 28.7% in 1997 to 9.4% in 2004, as illustrated in Figure 6. The decrease was 19.3% (95% CI 8.6%–30%, $p < 0.0005$).

The majority of the fatalities were found at the site of injury after death. Of the 163 victims who died from penetrating injury during the period, only 14 (8.6%) died during treatment and transportation, and 10 (6.2%) died in a hospital. Among these 24 victims found alive and who

subsequently died, there was no significant change in the frequency of death by year during the study period.

Paramedic and first responder activities

Although the paramedics were trained in a number of advanced lifesaving skills (10), only a few advanced procedures were actually used with these 2,349 victims. Ten patients had endotracheal intubation performed; none of these cases were penetrating injuries, and seven died. CPR was performed in 21 victims, of whom 11 died. The survivors had either medical emergencies, poisoning, or decreased consciousness resulting from blunt injury. Mouth-to-mouth rescue breathing was performed with 53 victims. Although 2,045 victims had IV lines placed, only 24 had their external jugular vein cannulated. Venous cut-down was not performed.

In a retrospective review of a sample of patients assisted by first responders in 2003, we assessed the first responders' activities in detail in 78 cases. The activities performed by the first responders are summarized in Table 3.

DISCUSSION

This study shows the ability of a low-tech prehospital emergency system designed for penetrating trauma to adapt to changes in injury patterns. Prehospital treatment effect was as good in the new groups of patients as it was in the original target group of mine- and war-related injuries. The system has matured by reducing time to first medical help and based on improved physiological parameters after prehospital treatment during the eight-year study period. The

study confirms our preliminary findings of decreasing mortality after penetrating war-related injuries in a rural setting (9).

While previous studies by our group and others have focused mainly on hard endpoints in victims of trauma, such as death and physiological deterioration, this study adds the factor of the adaptability of a system developed for mine injuries to care for a number of other medical needs in the rural population. It also shows that with local leadership, the program has matured with steadily improved results and reduced time to first medical help, and managed to select dedicated paramedics in appropriate areas with the highest load of injuries and lack of alternative medical resources.

We have previously demonstrated that a prehospital trauma system consisting of layperson first responders and paramedics with limited theoretical skills is useful in penetrating trauma and landmine injuries (9). A system like this should ideally be able to respond to changing patterns of injury to adapt to the needs of the society served. The changes in the injury distribution in this study population arose from changes in the society and were not foreseen during the planning of the training course for handling mine and penetrating injuries. Improved economic conditions, and to some degree mine clearance, reduced the incidence of mine injuries as the need for entering the minefields for firewood collection and animal herding decreased. The better economy also increased road traffic and thus road traffic injuries. When the paramedics and first responders can respond to a changing injury pattern without compromised treatment results, we consider this a sign of good adaptation.

In this study, one of the outcome measures was the change in physiological function after prehospital trauma care by paramedics and first responders. An indication of the robustness of this outcome measure is the fact that improvement in physiological function in penetrating

injuries, when stratified based on the ISS, followed the pattern found from stratifying based on the initial PSS. The ISS was not assessed for victims with blunt injury because of the patient referral system in Northern Iraq. However, the ROC curves demonstrated a high accuracy of the pre-intervention PSS as a predictor for death for both penetrating and blunt injury. We also used physiological severity for the remaining group of patients consisting of medical emergencies, obstetrics, drowning, burns, and scorpion stings. For this group, the ROC curve indicated an area under the ROC curve close to a “reasonably powerful model” as a predictor of death (16). To the best of our knowledge, physiological severity scores like the Revised Trauma Score have not previously been used to evaluate this group of mixed rural patients in a low-income country setting. It is remarkable that the distribution of improvement in relation to severity was so consistent with that of the penetrating and blunt injuries.

We used a simplified physiological scoring system as compared to the Revised Trauma Score (15). This decision was based on the need for a tool to assess the physiological impact of injury that could be used in rural settings by non-graduate paramedics and first responders, and primarily for recognition of severely injured victims at high risk during a long transport (14). The use of computation vectors designed for quite another setting with short transportation times and patients without pre-injury disease and malnutrition may seem dubious; however, we have previously shown that using the respiratory rate alone is justifiable in rural areas with long transportation times, although larger studies are needed to clarify this (14). The lack of large patient cohorts and validated vectors is an obvious weakness of the present study.

A core component of the present program was that paramedics trained fellow villagers as first responders. This intervention was planned and adapted locally to suit the society and local habits. The fact that more than 6,000 villagers have participated and that requests for training

courses are continuous emphasizes the acceptance and support for this intervention in the target area. This availability of first responders has a number of implications, and one we can quantify is the reduced time from injury to first medical help. When considering the range of activities performed by first responders and the way paramedics organized first responders to work in teams, we regard the treatment results in many of the more severe cases as dependent on the cooperation between paramedics and first responders. We thus hypothesize that first responders have an individual significant impact on reducing mortality, but the design of the intervention does not permit comparison of paramedics with and without first responders or first responders to trained paramedics, even though this comparison recently has been suggested (7). There are good reasons to believe that simple measures applied early are most important to the majority of trauma victims (18-20). The great number of procedures performed by the first responders underlines the need for trained assistants to the paramedics.

The present program is functioning in an area of great social change. The population has been living through social unrest and war during the intervention period, and the local economy has changed dramatically through the last years. The salaries paid to the paramedics have by intention been in the lower level of village salaries to inspire the paramedics to continue in their previous work. It is remarkable that 70% of the paramedics were still retained after nine years when they could make far higher salaries in the cities. This outcome is in contrast to findings from other low-income countries (21). We consider the selection process of new trainees to be of utmost importance (11, 21). In addition, a close follow-up from a local physician with continued teaching and guidance is crucial.

A further sign of maturation and local acceptance has been the invitation to train paramedics in local hospitals. Although the program started with the understanding and

collaboration of local authorities, it was only after some years of existence that training of paramedics in district hospitals became acceptable to the physicians in these hospitals. We consider the request to the local physician to assume responsibility for organizing the complete trauma system in the province a proof of sustainability and acceptance.

The findings of this study can be challenged based on several limitations. Ideally, studying the effects of an intervention like this should be done in a randomized and controlled fashion with blinded observers. Due to the conditions for provision of training and medical support in Northern Iraq a randomized controlled study was not feasible. Data gathering with the meticulous design applied in this study without any accompanying treatment would seem highly unethical in a setting with approximately 30% mortality after mine injuries. As an alternative we have tried to choose robust outcome measures. In this respect mortality and time intervals should be fairly well defined, although a reliable hospital mortality rate after non-penetrating injury was unavailable due to the hospital referral system in Northern Iraq. The evaluation of physiological function depends on correct and reliable reporting by the paramedics responsible for each patient. The validity and reliability of blood pressure measurement, counting of respiratory rate and assessment of mental function were checked during the training courses. In addition, we found excellent agreement between assessment done by paramedics at hospital admission and the first assessment at the hospital.

In conclusion, we found that a low-tech prehospital trauma care system that was originally designed for penetrating trauma could adapt to changing injury patterns in the population and gradually evolve from trauma care to a more universal resource for the villages served. In addition, the system matured over time as a result of careful selection of paramedics and training of village first responders; thus the time intervals before medical help could be provided were

reduced, decreasing the physiological impact of injuries and illness. Finally, the system was gradually accepted at all levels of local authority and is now used as a model for trauma care in Kurdistan, Northern Iraq.

ACKNOWLEDGEMENT

We want to thank Professor Stig Larsen, Center of Biostatistics and Research Methodology, Norwegian School of Veterinary Science, Oslo, Norway for assisting in agreement analysis statistics.

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Table 1. Paramedics trained in a prehospital trauma system in Northern Iraq during the period 1996–2004.

Time period	1996–1999	1999–2002	2002–2004	2004	Total
No. of paramedics certified	20	25	21	22	88
No. without formal medical education	9	5	2	0	16
Still present in program November 2005	9	19	15	20	63
Retention rate (%)	45	76	71	91	72

Table 2. Physiological severity score (PSS) before treatment and treatment effect in groups of patients over age 16 stratified into thirds based on initial severity score. Values are mean with 95% confidence interval.

	Mean PSS before treatment	Treatment effect
Penetrating injury (n = 619)		
High severity (n=206)	5.79 (5.63–5.95)*	1.30 (1.12–1.47)*
Moderate severity (n=207)	7.08 (7.05–7.11)*	0.65 (0.57–0.73)*
Light severity (n=206)	7.80 (7.79–7.82)*	-0.05 (-0.15–0.04)*
ISS > 15 (n=39)	5.62 (5.10–6.14)*	0.99 (0.48–1.50)
ISS 9–15 (n=192)	6.66 (6.54–6.79)*	0.96 (0.85–1.07)
ISS < 9 (n=244)	7.46 (7.39–7.53)*	0.30 (0.20–0.40)*
Blunt injury (n = 420)		
High severity (n=140)	4.90 (4.66–5.13)*	1.37 (1.14–1.60)*
Moderate severity (n=140)	6.74 (6.69–6.80)*	0.84 (0.75–0.93)*
Light severity (n=140)	7.75 (7.72–7.78)*	-0.1 (-0.29–0.01)*
Other injuries and medical emergencies (n = 575)		
High severity (n=192)	4.93 (4.74–5.11)*	2.01 (1.82–2.21)*
Moderate severity (n=192)	6.58 (6.53–6.62)*	1.01 (0.87–1.16)*
Light severity (n=191)	7.35 (7.30–7.39)*	0.47 (0.42–0.52)*

* Differences within groups significant at $p < 0.05$

ISS = injury severity score

Table 3. Procedures performed by first responders in 78 cases during 2003.

	N	%
Opening of airway/recovery position	45	58
Keep patient in semi-sitting position	37	47
Compression of artery	43	55
Elevation of bleeding limb	51	65
Gauze packing of wounds	63	81
Application of long elastic bandage	65	83
Keep patient warm, blankets	69	88
Take care of relatives	44	56
Carrying the patient	66	85
Organizing the transportation	77	99
Comforting the victim	78	100

Figure legends.

Figure 1. Number and type of injuries receiving prehospital treatment by paramedics in rural Northern Iraq in the years 1997 to 2004.

Figure 2. Distribution of injury categories in three time periods.

Figure 3. Time interval from injury to first in-field medical response.

Figure 4. Effect of prehospital treatment in all patients in a prehospital emergency care paramedic system in Northern Iraq in the period 1997–2004 measured as improvement in the Physiological Severity Score (Δ PSS).

Figure 5. Agreement between the last physiological assessment done by paramedic and the first assessment done by the receiving hospital in a Bland & Altman plot. The dotted lines indicate the upper and lower agreement boundaries.

Figure 6. Mortality after landmine and penetrating injuries for all victims in a prehospital emergency care paramedic system in Northern Iraq in the period 1997–2004.

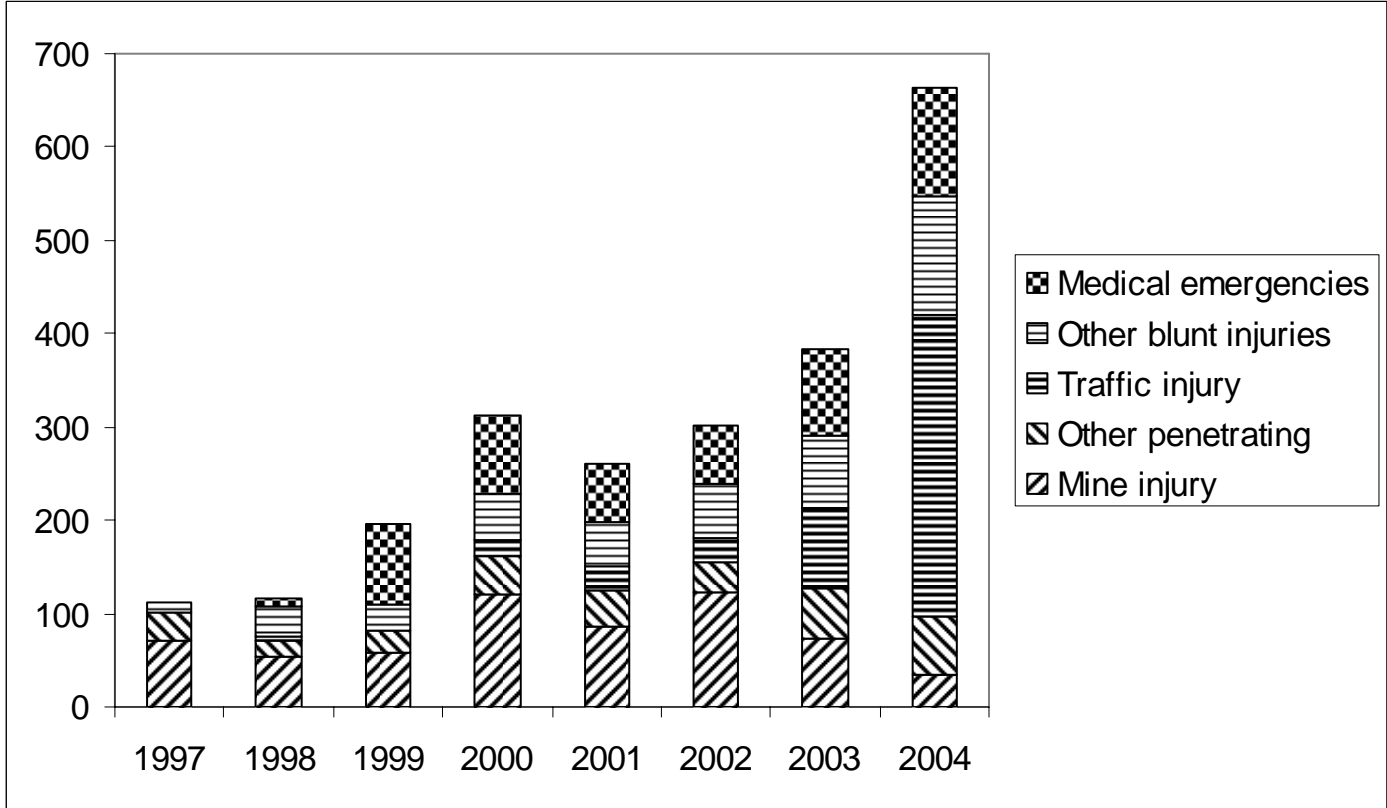


Figure 1

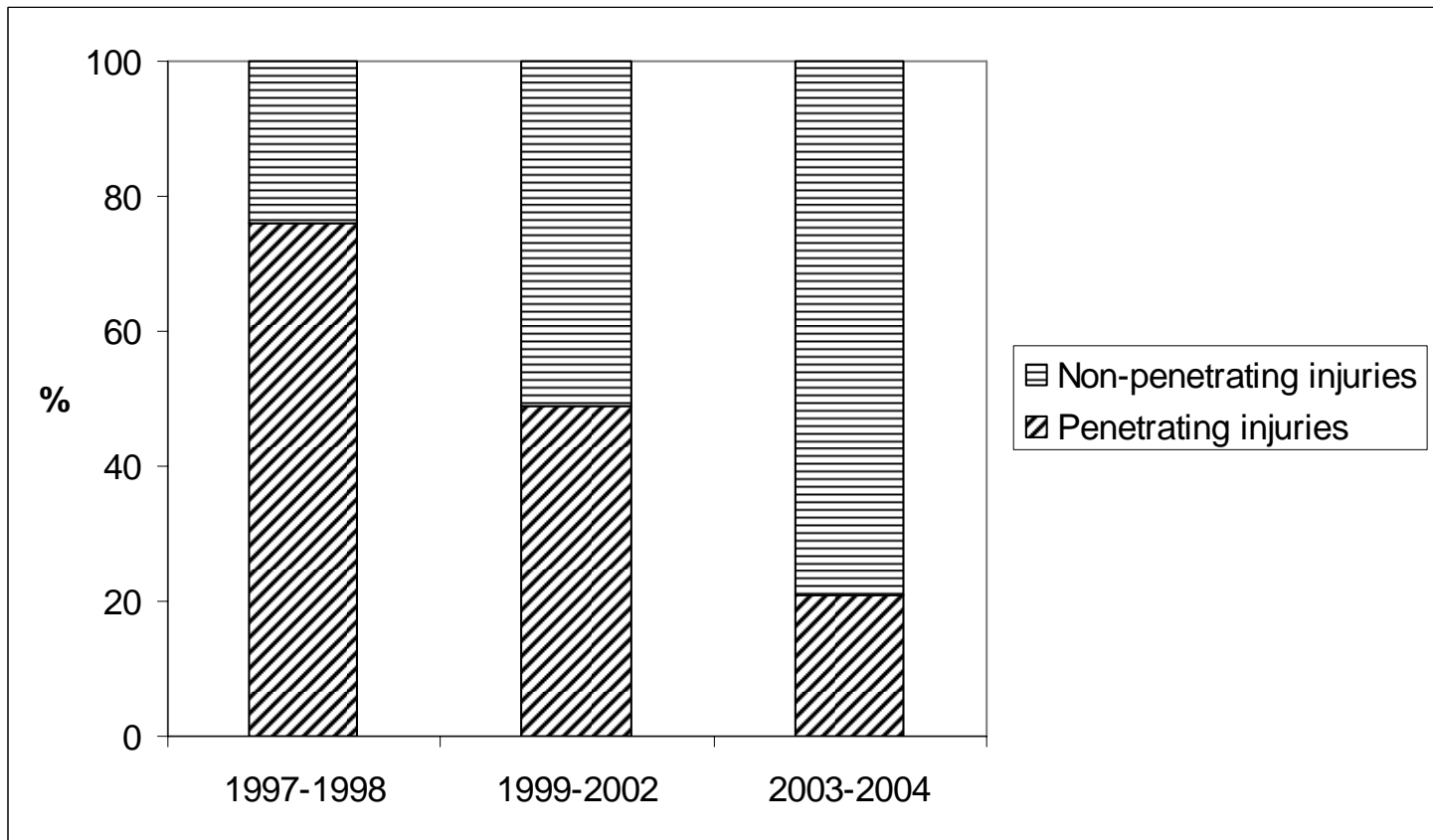


Figure 2

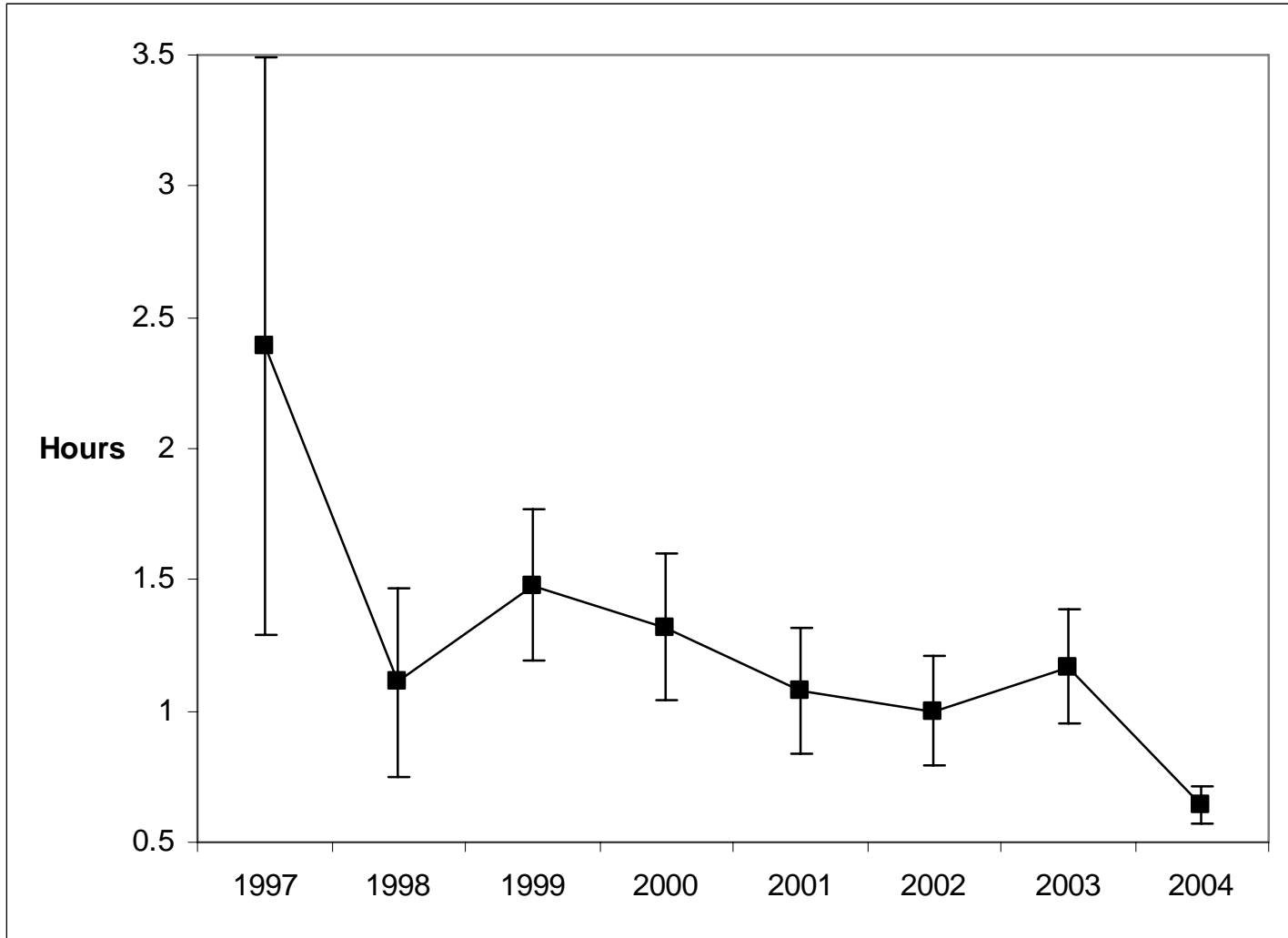


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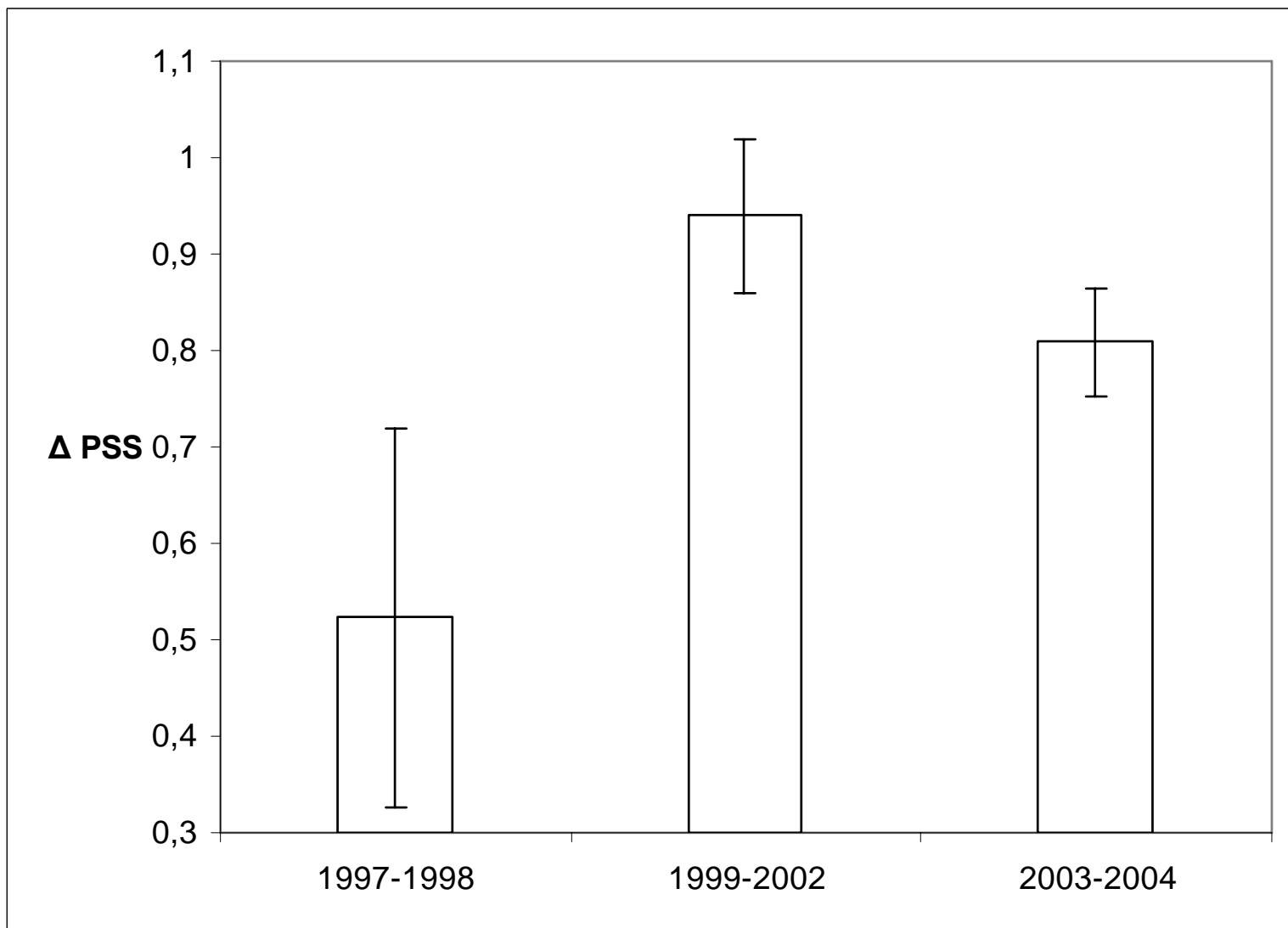


Figure 4

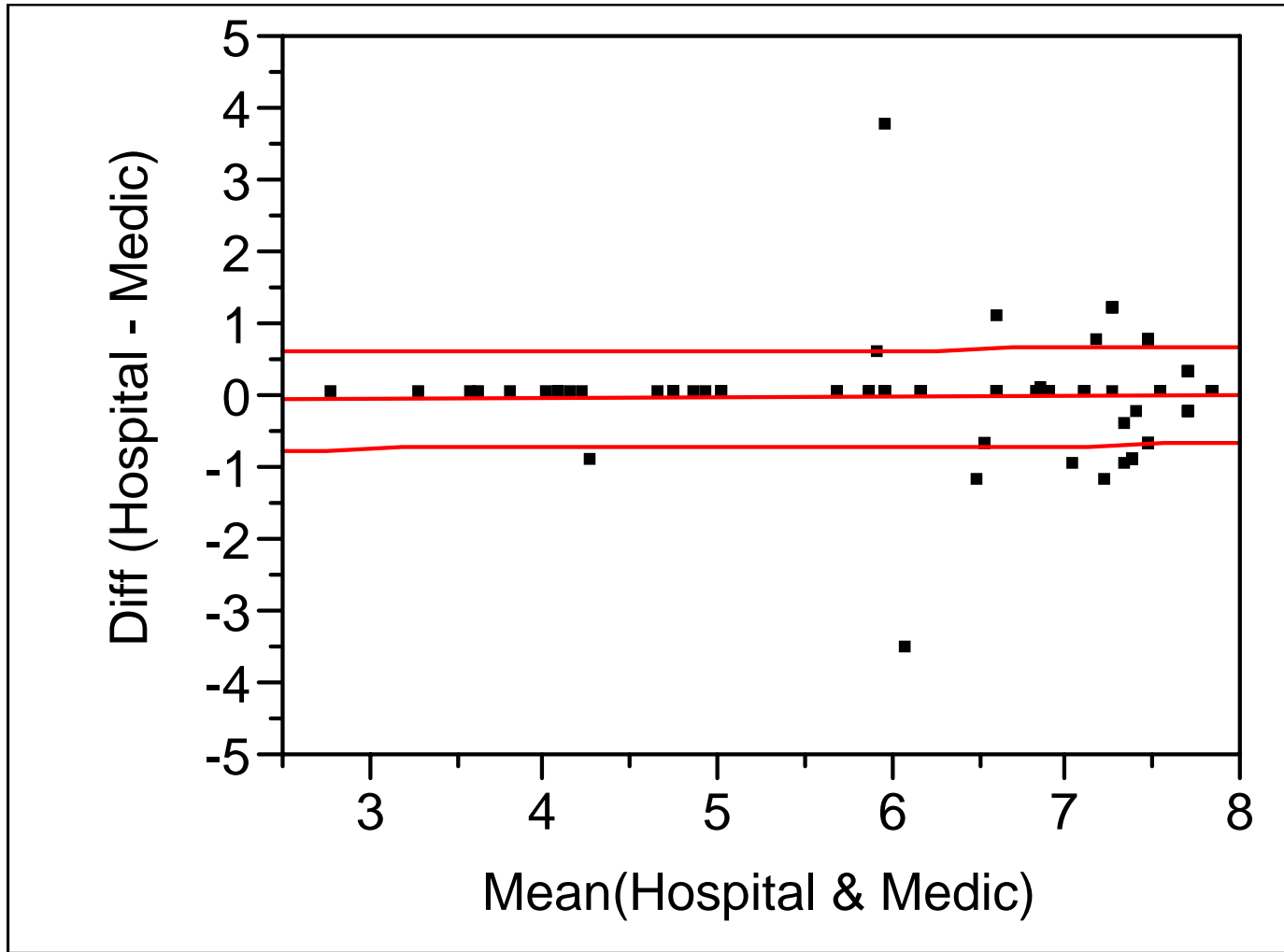


Figure 5

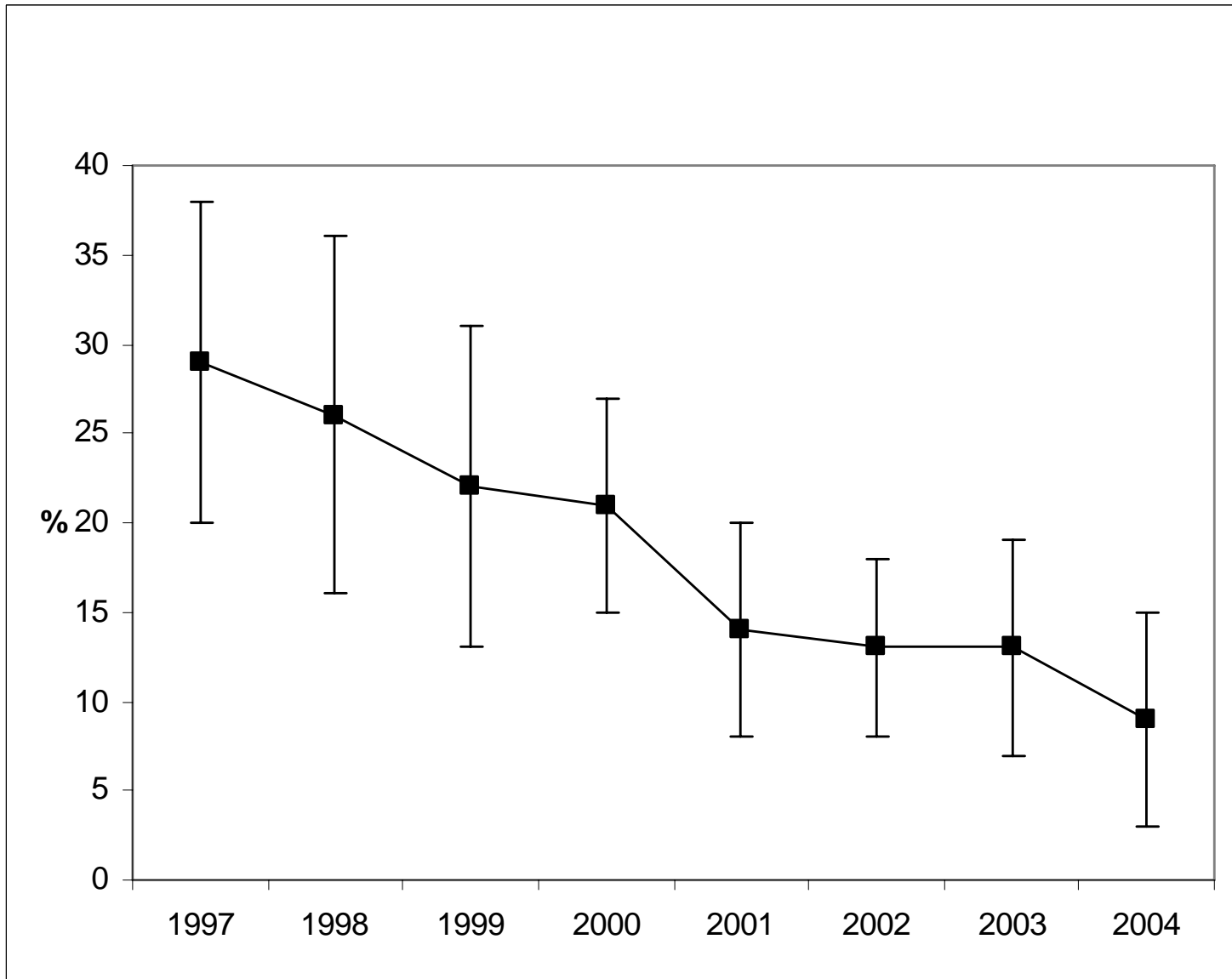


Figure 6