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Prevalence of laser beam exposure and associated injuries

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Abstract

Background: An increasing number of consumer laser products are available to Canadians, many being purchased from online retailers. Of particular concern are high-powered, handheld laser devices. This study was conducted to assess the impact of this influx of laser products on the number of laser-associated injuries in Canada.

Data and methods: The rapid response component of the 2014 Canadian Community Health Survey collected data from 19,765 Canadians on the prevalence of laser product exposure and usage, the type of laser product used, and the incidence of eye or skin injuries.

Results: Approximately half of Canadians (48.1%) reported using or being exposed to a laser product in the previous 12 months. The highest laser product usage or exposure was among those with university education (58.6%) and those with higher income categories ($p < 0.0001$). The highest prevalence of exposure or usage involved laser scanners (38.7%), laser pointers (11.1%) and lasers for entertainment (9.7%). Overall, about 1% of Canadians reported discomfort or injury involving a laser product in the past 12 months. Over half the injuries (59.1%) occurred to the eyes. Most of the injuries (74.9%) resulted from someone else's use of the device. The majority of the reported injuries were caused by lasers for cosmetic treatment or laser pointers.

Interpretation: Despite the prevalence of laser product usage and exposure among Canadians, a low percentage of respondents reported injuries. This is likely because most laser devices are low-powered and typically do not represent a hazard. Nonetheless, efforts to increase awareness of laser product risks may be beneficial given the findings of this study.

Keywords: Laser, consumer products, devices, pointers, eye injury, skin injury

Since the 1990s, improvements in laser technology and reduced manufacturing costs have facilitated the integration of laser products into daily life in an expanding array of applications, including medicine and cosmetics, security, communications, instrumentation, and entertainment. Many novel and low-cost laser products are increasingly available in the consumer marketplace. This is reflected by an increase in laser product sales, with industry analysts reporting a rise in total revenue for the global laser market from $6.32 billion in 2009 to $9.56 billion in 2014 (an increase of 51%).[1]

The International Commission on Non-Ionizing Radiation Protection (ICNIRP) is an independent organization of scientific experts that provides advice on the health and environmental effects of nonionizing radiation, including laser radiation. ICNIRP has established guidelines on limits of exposure to laser radiation.[2] These exposure limits serve as the scientific basis for the hazard classification by the International Electrotechnical Commission (IEC) of laser devices (i.e., classes 1, 1M, 1C, 2, 2M, 3R, 3B and 4) according to their accessible radiation properties (IEC 60825-1).[3]

The IEC classification of the hazard level of laser devices is based on the accessible exposure level, wavelength, emission duration and angular subtense of the apparent source (i.e., beam geometry and radiation pattern). According to the IEC standard, laser devices with a beam below the accessible emission limit of Class 3R represent a minimal risk to the eye since there are adequate safety margins, innate rapid aversion responses and blink reflexes. As a result, unintentional or reflected exposures would rarely reflect worst-case conditions. However, the risk of injury is still present with the use of telescopic optics and intentional viewing, and this risk increases with exposure duration. Exposure to a direct or reflected high-powered (Class 3B and Class 4) laser beam has the potential to cause serious eye or skin damage and may also pose a fire hazard.[3]

The increasing availability and sales of consumer laser products to Canadians, particularly through online purchases of high-powered handheld lasers, may increase the risk of ocular or skin injuries caused by laser radiation exposure. Currently, estimates of the prevalence of laser injury can be derived only from published accounts (e.g., case reports) in the scientific literature. Published accounts of injuries likely represent a small percentage of the total number of laser injuries sustained. The majority of incidents would not be formally published in scientific journals, since they are not typically reported outside the clinical setting.[4] The lack of information regarding the prevalence among Canadians of injuries caused by laser product usage or exposure presents a challenge for surveillance, risk assessment and risk management.

In 2014, Health Canada provided questions pertaining to the prevalence of and injury from laser product usage or exposure in the previous 12 months on Statistics Canada's nationally representative Canadian Community Health Survey (CCHS). This information was gathered to support efforts to monitor and address an emerging health concern regarding laser products. Specifically, the CCHS data assisted in analyzing parameters such as:

- the prevalence of laser product usage or exposure
- the frequency and type of injury sustained, as well as whether the injury was the result of personal use or someone else's use

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What is already known on this subject?

- In recent years, because of decreased production costs, laser devices have become increasingly prevalent in a variety of consumer products (including children's toys) for use in "uncontrolled environments." In uncontrolled environments, laser radiation may not be contained or characterized, and users or bystanders may be unaware of the intensity or hazards associated with a laser and may not be able to mitigate the risk using safety measures.
- Prolonged deliberate staring (e.g., 1 s to 10 s) into a laser beam or the deliberate suppression of the natural aversion responses to laser exposure could result in ocular injury. Protection is afforded only for Class 1M, 2, 2M, 3R, 3B and 4 laser devices by knowledgeable and responsible use of such devices.
- Infants and children have a more transmissive lens than adults to ultraviolet and blue light and do not have fully developed aversion responses to ultraviolet and blue light. Furthermore, ICNIRP (2013) has stated that its exposure limits in the 300 nm to 400 nm range do not adequately protect the retina of infants.

What does this study add?

- This article identifies that an estimated one-half of Canadians use or are exposed to laser products.
- Among Canadians who use these products, 1.1%[E] reported injury or discomfort.
- The majority of injuries were to the eyes, and the remaining injuries were to the skin.
- Injuries were often the result of someone else's use of a laser and less often the result of the operator's own use of the device.
- Injuries were most commonly reported following cosmetic laser treatments and exposure to laser pointers.

- the type of laser products being used and most likely to cause injury
- where the laser products were obtained.

This information will help improve the knowledge base in Canada regarding laser injuries. This will also strengthen risk assessment of laser products, inform risk management strategies, and support evidence-based advice and recommendations.

Data and methods

Data sources

Statistics Canada's CCHS collects health-related data from the Canadian population for use at the national, provincial and regional levels. Derived from Cycle 4 of the CCHS, the rapid response data analyzed in this article were collected during telephone surveys conducted from March to June 2014. Respondents were asked about their laser product usage or exposure during the previous 12 months.

The CCHS questionnaire was administered directly to respondents using computer-assisted telephone interviewing. The CCHS covers the household population aged 12 or older in the provinces and territories. The survey excluded:

- people living on reserves and other Aboriginal settlements in the provinces
- full-time members of the Canadian Forces
- residents of institutions
- residents of the Quebec health regions of Nunavik and Terres-Cries-de-la-Baie-James.

Together, these exclusions represented less than 3% of the population aged 12 or older. The rapid response module of the CCHS on laser beam exposure covered the same population as the CCHS, except that it excluded participants from the three territories (i.e., Yukon, the Northwest Territories and Nunavut).

Overall, 31,709 households were in scope for the CCHS rapid response module on laser beam exposure. Valid responses were obtained for 19,765 individuals. This yielded an overall response rate of 62.3%. A detailed description of the CCHS methodology and sources used is available on the Statistics Canada website.

Measures

The CCHS rapid response laser beam exposure module was organized into sections. The first set of questions asked respondents whether they used or were exposed to a laser product in the previous 12 months. Respondents who responded positively were asked to identify the type of laser product they used or were exposed to. Respondents were presented with the following product options:

- laser pointer for presentations
- laser survey tool for levelling or distance measurement, or range finders
- laser for cosmetic treatments for hair or tattoo removal, excluding medical devices
- laser for entertainment such as a toy, game or light show display
- laser for materials processing such as cutting or marking
- laser scanner such as a barcode reader (for example, a self-checkout scanner)
- any other product, excluding medical devices.

Respondents who replied positively to using or being exposed to a laser product were next asked about any injury or discomfort they experienced. They were asked what body part was affected (i.e., eye, skin, other), as well as about the frequency and duration of the discomfort or injury. Respondents with multiple reports of discomfort or injury were asked to provide answers for the worst injury or discomfort they sustained.

The last set of questions pertained to the type of laser device that caused the discomfort or injury, where the device was obtained and whether the injury was the result of personal use or someone else's use of the device.

All the questions are available on the Statistics Canada website.

Statistical analysis

The analyses were based on a sample of 19,765 respondents aged 12 or older in the 10 provinces. To be representative of the Canadian population, the data were weighted and analyses were carried out using SAS EG 5.1 (SAS Institute Inc., United States). The SAS procedure SURVEYFREQ was used to calculate percentages and coefficients of variation (CVs). Data with a CV from 16.6% to 33.3% are identified by an (E) and should be interpreted with caution; data with a CV greater than 33.3% are suppressed (F) because of extreme sampling variability. To test differences in prevalence between sociodemographic groups, the procedure SURVEYLOGISTIC was used to calculate odds ratios (ORs) and corresponding confidence intervals (CIs) with Bonferroni adjustments for pairwise comparisons. The ESTIMATE statement of the procedure SURVEYLOGISTIC was used to test for a linear trend in the use of or exposure to a laser device across income levels. Both procedures accounted for sampling weights and estimated variance using bootstrap weights.

Results

In 2014, 48.1% of Canadians aged 12 or older (an estimated 14.5 million) reported using or being exposed to beams from a laser device in the previous 12 months. A small but statistically significant sex difference was present: the odds of Canadian males using or being exposed to a laser device were 1.12 times higher than for females (Table 1). A higher prevalence of exposure was also reported in each age group compared with the 45 or older age group.

Education appeared as a significant factor associated with laser use and exposure. The prevalence of laser use or exposure was 58.6% among Canadians with a "university certificate, diploma or degree," which was higher than among those with "some postsecondary education (certificate or diploma including trades)" (50.2%; 1.4 OR; 95% CI: 1.21, 1.62; data not shown) and among those with a "secondary diploma or equivalent or less" (39.1%; 2.11 OR; 95% CI: 1.84, 2.42) (Table 1). A statistically significant ($p < 0.0001$) positive linear trend in the use of or exposure to laser devices was also present across income levels, such that the higher the household income, the higher the probability of using or being exposed to a laser device. Canadians who were self-employed reported a slightly lower prevalence of exposure or usage of laser products compared with those who were employed by a company or organization (53.4% versus 58.7%) (Table 1).

Compared with the prevalence in Ontario, the prevalence of Canadians who were exposed to or used laser products was found to be significantly higher ($p < 0.05$) in the Western provinces (i.e., Manitoba, Saskatchewan, Alberta and British Columbia) and significantly lower ($p < 0.05$) in Quebec (Table 1).

Table 2 represents the weighted distribution of respondents that used or were exposed to laser products, with distributions shown for different product types.

Table 1
Prevalence and unadjusted odds ratios relating to laser beam equipment use or exposure in past year, by selected characteristics, household population aged 12 or older, Canada excluding territories, 2014

Characteristic	%	95% confidence interval from	95% confidence interval to	Odds ratio	95% confidence interval from	95% confidence interval to
Sex						
Female†	46.9	45.3	48.5	1.00	...	...
Male	49.4	47.7	51.0	1.12*	1.03	1.23
Age group						
12 to 17	54.5	50.7	58.3	2.14*	1.70	2.71
18 to 34	63.4	61.0	65.7	3.05*	2.60	3.58
35 to 44	58.7	55.4	62.0	2.46*	2.01	3.01
45 or older†	35.8	34.2	37.3	1.00	...	...
Education						
Secondary diploma or equivalent or less†	39.1	37.4	40.7	1.00	...	...
Some postsecondary education (certificate or diploma including trades)	50.2	48.2	52.1	1.50*	1.32	1.71
University certificate, diploma or degree	58.6	56.2	61.0	2.11*	1.84	2.42
Not applicable / Don't know / Refusal / Not stated	39.2	30.9	47.6	...	...	...
Worked at job						
Yes	57.3	55.7	58.8	2.62*	2.34	2.94
No†	33.8	31.7	35.9	1.00	...	...
Not applicable / Don't know / Refusal / Not stated	20.4	18.2	22.5	...	...	...
Employment status						
Employee	58.7	57.0	60.5	1.23*	1.04	1.45
Self-employed / Family business no pay†	53.4	49.5	57.3	1.00	...	...
Not applicable / Don't know / Refusal / Not stated	33.6	32.1	35.2	...	...	...
Household income						
$39,999 or less	31.4	29.5	33.3	...	...	...
$40,000 to $69,999	45.1	42.8	47.4	...	...	...
$70,000 to $99,999	51.6	48.8	54.4	...	...	...
$100,000 to $149,999	58.3	55.4	61.2	...	...	...
$150,000 or more	62.9	59.8	66.0	...	...	...
Not applicable / Don't know / Refusal / Not stated	62.5[E]	41.2	83.8			
Region						
Western provinces	55.0	52.9	57.1	1.24*	1.05	1.46
Quebec	36.7	34.3	39.1	0.59*	0.49	0.71
Atlantic provinces	47.4	45.1	49.7	0.93	0.78	1.10
Ontario†	49.5	47.4	51.6	1.00	...	...

... not applicable
[E] use with caution
* significantly different from reference category ($p < 0.05$)
† reference category
Source: 2014 Canadian Community Health Survey.

The most commonly reported product types by those who used or were exposed to a laser device included laser scanners, laser pointers, lasers for entertainment and laser survey tools (Table 2). Sex differences were observed depending on the type of laser product. A significantly ($p = 0.0109$) higher proportion of females (51.7%) reported being exposed to or using laser scanners than males (48.3%). The prevalence of laser pointer usage or exposure was significantly ($p < 0.0001$) higher for males than females (58.5% versus 41.5%). Use or exposure to lasers for entertainment was significantly ($p = 0.0023$) higher among males than females (55.0% versus 45.0%). A significantly ($p < 0.0001$) higher proportion of males used laser survey tools (81.0% versus 19.0%) (Table 2). More specifically, the odds of using or being exposed to laser pointers were 1.5 times higher for males than for females. Conversely, females had 4.2 times higher odds of using or being exposed to cosmetic lasers than males (data not shown).

Among Canadians who reported using a laser product, 1.1%[E] (95% CI: 0.7, 1.4) reported experiencing discomfort or injury within the past 12 months. This included skin injuries such as rash, itch or pain and eye injuries such as itchiness, pain, visible floating objects, blurred vision, burn, flash blindness, excessive watering or loss of sight (Table 3). Approximately 44.9%[E] of the respondents who reported an injury indicated it occurred only once in the past 12 months, while 49.5%[E] indicated at least two occurrences in the past 12 months (Table 3). Among those who reported an injury from a laser product, 41.3%[E] declared the injury or discomfort occurred to their skin, while 59.1% reported an injury to the eyes. Sight injury prevalence did not appear to vary by sex (data not shown). Among those who reported harm caused by a laser device, 63.9% indicated that the discomfort or injury lasted two days or less, while 34.0%[E] of individuals reported that the injury lasted more than two days (Table 3).

When recalling their discomfort or injury, respondents were asked what type of laser product, excluding medical devices, caused the harm. The majority of injuries were the result of cosmetic laser treatments (e.g., hair or tattoo removal) (39.1%[E]). Laser pointers accounted for 26.3%[E] of injuries, while survey tools, lasers for entertainment, lasers for materials processing, laser barcode scanners and other laser products not identified in this survey accounted for the

Table 2
Weighted distribution of respondents who have used or been exposed to laser equipment, by product type, in past year, selected characteristics, household population aged 12 or older, Canada excluding territories, 2014

	Total			Males			Females†		
		95% confidence interval			95% confidence interval			95% confidence interval	
Product type used or exposed to	%	from	to	%	from	to	%	from	to
Laser pointer for presentations	11.1	10.3	11.8	58.5*	55.1	61.8	41.5	38.2	44.9
Laser survey tool for levelling or distance measurement, or range finders	7.3	6.7	7.8	81.0*	77.7	84.4	19.0	15.6	22.3
Laser for cosmetic treatments for hair or tattoo removal, excluding medical devices	2.8	2.5	3.2	19.1*[E]	11.8	26.4	80.9	73.6	88.2
Laser for entertainment such as a toy, game or light show display	9.7	9.0	10.4	55.0*	51.8	58.1	45.0	41.9	48.2
Laser for materials processing such as cutting or marking	2.6	2.3	3.0	86.6*	82.5	90.8	13.4	9.2	17.5
Laser scanner such as a barcode reader	38.7	37.5	39.9	48.3*	46.9	49.6	51.7	50.4	53.1
Any other product, excluding medical devices	2.5	2.2	2.9	64.4*	58.5	70.4	35.6	29.6	41.5
At least one of the above	48.1	46.9	49.3	50.6	49.5	51.8	49.4	48.2	50.5

[E] use with caution
* significantly different from reference category ($p < 0.05$)
† reference category
Source: 2014 Canadian Community Health Survey.

Table 3
Weighted distribution of respondents who used or were exposed to a laser beam over the past 12 months who experienced discomfort or injury involving a laser product, household population aged 12 or older, Canada excluding territories, 2014

		95% confidence interval	
Factor	%	from	to
Discomfort or injury involving a laser product			
Yes	1.1[E]	0.7	1.4
No	98.9	98.5	99.2
Discomfort or injury involving laser product—number of times			
1 time	44.9[E]	27.6	62.1
2 to 260 times	49.5[E]	32.2	66.7
Type of discomfort or injury			
Skin	41.3[E]	24.1	58.5
Eye	59.1	41.9	76.3
Length of discomfort or injury			
Two days or less	63.9	45.2	82.6
More than two days	34.0[E]	15.2	52.9
Own use or someone else's			
Your own use of the device	25.0[E]	12.1	37.8
Someone else's use of the device	74.9	62.0	87.7
Type of laser that caused injury, excluding medical devices			
Pointer	26.3[E]	11.7	40.9
Cosmetic treatments	39.1[E]	21.7	56.6
Survey tool / Entertainment / Materials processing / Scanner / Other	34.1[E]	18.4	49.8

[E] use with caution
Source: 2014 Canadian Community Health Survey.

remaining 34.1%[E] of injuries (Table 3). Interestingly, 74.9% of respondents indicated that their injury was the result of someone else's use of a laser product, while approximately 25.0%[E] reported their injury was caused by their own personal use of a laser product (Table 3).

Discussion

Historically, laser devices were typically located in medical, industrial, commercial, research and military settings because of the cost and complexity of operating these devices. As a result, the safety of operating laser devices could be controlled through occupational training and the education of users regarding laser safety principles.[5] In recent years, decreased production costs have led laser devices to become increasingly prevalent in a variety of consumer products, including children's toys. The increasing prevalence of consumer laser products, especially high-powered devices, may represent an increasing risk to Canadians, particularly if consumers lack the competency, knowledge or skills required to operate these devices safely. The use of Class 3B and 4 laser devices in an uncontrolled setting, particularly by an untrained or unknowledgeable operator, creates a risk not only to the user but also to observers and bystanders who may be unaware of the risks associated with laser exposure and may not be able to mitigate the risk using appropriate safety measures.

Since 2012, the manufacturing, advertising, import, lease and sale of high-powered (i.e., Class 3B and 4) handheld, battery-operated lasers and laser pointers has been prohibited in Canada.[6] Despite restrictions on the sale, lease or import of high-powered laser pointers in many countries, several recent studies have reported that a large number of laser pointers labelled as low-powered devices (e.g., Class 1, 2 or 3R) were found to exceed their claimed IEC 68025-1 classification level and were actually Class 3B devices.[7–9] In 2013, National Institute of Standards and Technology researchers found that nearly 90% of green laser pointers and about 44% of red laser pointers tested were non-compliant with U.S. federal safety regulations. Half of these devices exceeded the accessible emission limit for Class 3R laser devices by a factor of two or more.[7] Furthermore, Internet purchases with direct shipping from overseas vendors to Canadian consumers represent a challenge for the enforcement of the existing prohibition, especially if the laser class is not accurately represented on the product. This may result in an increased number of high-powered, handheld battery-operated laser devices in the hands of Canadians. Consequently, the surveillance of the prevalence of laser device usage and injury among Canadians is important for monitoring the risk that laser devices pose to Canadians.

The current study results indicated that approximately one-half of Canadians have used or been exposed to laser devices in some form in the previous 12 months. Males reported a higher prevalence of laser product usage or exposure. Sex differences become more apparent with certain laser product categories. A higher proportion of males used or were exposed to lasers for entertainment or measurement purposes, whereas females were more likely to use or be exposed to lasers for cosmetic reasons. Approximately 1% of users indicated they had suffered a laser-related injury or discomfort in the past year, among which harm to the eyes was more prevalent.

According to the CCHS, cosmetic laser treatments (e.g., hair or tattoo removal) were the cause of most injuries or discomfort (39.1%[E]). This may be because of the nature of the treatment itself, particularly to the skin, or because aestheticians, cosmetologists or individuals have no formal training, or inadequate training, or lack experience operating such devices. Several studies have suggested that misuse may be the cause of injuries from elective cosmetic procedures since these procedures are often associated with unlicensed and inadequately trained personnel.[10–16] These types of injuries (resulting from the misuse of products) may be more prevalent because unlicensed establishments often offer more affordable rates for their procedures. This places individuals who seek these treatments at higher risk. That being said, many cosmetic procedures can cause discomfort or mild injury to the skin to achieve the desired cosmetic outcome.

Sex differences regarding use or exposure identified in the survey were supported by published case reports of harm from 1999 to 2016, in which the majority of laser injuries from cosmetic treatments (e.g., hair removal, skin treatment or tattoo removal) occurred in females,[10–16] whereas most injuries incurred from a laser pointer, entertainment or measurement device occurred among males.[4,9–29]

An analysis of published case reports since 1999[4,9–29] shows that of all the cases of eye injury caused by exposure to laser radiation, the majority involved the misuse of a handheld battery-operated laser product by an adult or a child. Most of these injuries were the result of irresponsible use or deliberate staring at a laser by a child, or the result of the inappropriate use of a high-powered laser device (Class 3B or 4) in an "uncontrolled environment".[4,9–29] The number of annual reported cases of eye injury caused by laser products has increased in the past decade. In 2008, no cases of eye injury caused by a laser products were reported. However, 29 cases of laser injury related to handheld battery-operated laser products were reported in 2014, accounting for 85% of all reported cases for that year. These injuries have occurred worldwide; however, a higher number of cases have been reported in Europe, the Middle East and North America. One case was reported in Canada in 2014.[17] In the cases reported in 2014 that included long-term follow-up injury reporting, about one-half of the ocular injuries resolved within one to two weeks, with the other 50% of patients sustaining longer-term visual impairments.[12–13,17–28]

While laser products were used in many consumer products prior to 1999, relatively few non-military laser injuries were reported in the scientific literature. At that time, most consumer laser products used red diode lasers (630 nm to 650 nm) that operated at a lower

accessible emission level because of limitations in laser technology at that time. Furthermore, published accounts of laser injuries may not have been captured. Most incidents would not have been presented in scientific journals as case reports or may have been misdiagnosed as an ocular disease.[29] Finally, laser trauma incurred in industrial, commercial, military and medical settings could go unreported because of a lack of knowledge regarding reporting systems. Some incidents may have gone unreported because a person failed to follow protocols (e.g., did not use protective eyewear) and feared workplace disciplinary action. Laser incidents in which eye or skin effects resolved quickly may also not have been reported.

Strengths and limitations

A number of limitations are associated with the findings of this study. The assessment for injuries was not ideal because the questionnaire did not report the specific type of injury incurred to each tissue type (i.e., eye [flash blindness, floaters or loss of sight] or skin [burns, pigment change or scarring]) and included discomfort in the same category. Furthermore, respondents were asked about injuries from lasers sustained only in the previous 12 months. Lifetime injuries, particularly among older respondents who no longer use such devices, may have provided a more comprehensive picture of the injury prevalence. Lastly, because of the small sample size of reported injuries, the statistics regarding the type of laser product (excluding medical devices) that caused the injury were coded as "E." This indicates a high degree of variability and that they should be interpreted with caution. Despite the low number of injury cases, the values are still reportable. However, the inclusion of a bigger sample size or of other national or provincial surveillance resources is required for a more accurate representation of the numbers and types of injuries that occur, as well as of the circumstances of the occurrence. One of the strengths of the survey is that the results are representative of the Canadian population. The survey had a large sample size of 19,765 respondents and an overall response rate of 62.3%, which is difficult to achieve for a survey of this kind. It is also the first of its kind to document the impact of laser device use in Canada. The survey suggests that the risk for harm is higher depending on the type of laser product used and who is using it.

Conclusion

The Canadian Community Health Survey findings indicate that consumer laser product usage and exposure are very prevalent among Canadians aged 12 and older. A detectable number of discomfort or injury cases within the past year were reported in this survey. Moreover, strong associations were observed between certain groups (e.g., age, sex), the type of devices that were used and the types of injuries reported. The data show that cosmetic laser treatments place females at greater risk for skin injury and that males are at greater risk of eye injury related to the use of survey tools, pointers or entertainment devices employing lasers. In summary, the majority of the laser injuries reported in this survey occurred to the eyes, as compared with the skin, and were usually the result of usage by another person. ■

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